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ORNITHOLOGY AND FOREST INSECT PESTS

BY W. L. TAYLOR, C.B.E.

(*Forestry Commissioner*)

ILL-DEFINED, and often ill-substantiated, statements that the behaviour of individual species of wild birds exerts influence, for good or evil, on the welfare of forests have appeared with almost automatic regularity in forestry text-books. The problem has mildly exercised the minds of British foresters, but has usually been regarded either from a very general view-point or judged from the local and seasonal activities of given species. Until quite recent times little or nothing has been done, in any part of the world, to investigate the inter-reactions of bird life and silviculture on a scientific basis, and agricultural research has been no more forthcoming in the application of ornithological knowledge. The common fault is to judge wild birds from the short-range aspect of the visible injuries they sometimes inflict, and to overlook their often less obvious good works. The activities of bird populations may be wholly beneficial, or, in respect of a few species, harmful in certain conditions and at certain seasons, but, on the balance of evidence, there is no room for doubt that the benefits afforded by a sufficient and suitably varied *avifauna* far outweigh any harm that can be attributed to the presence of birds in the woods, and that absence of bird life is a thing that foresters should deplore. Rough-and-ready classifications into harmful and helpful categories serve no useful purpose; systematic study of life-histories, habits, and dietaries is necessary before the status of any species can be assessed. According to present knowledge the only British bird deserving of outlawry is the wood pigeon; and even wild pigeons distribute acorns and have been known to consume insect larvae.

Ornithology has made great strides in recent years, and in Great Britain, thanks to the work of the British Trust for Ornithology, the Edward Grey Institute of Field Ornithology, and individual workers, reliable knowledge of the habits and diets of our wild birds continues slowly to increase. It must be admitted that forest research has not kept pace with the accumulating information, although some countries, notably the United States and Germany, have realized that bird problems are of more than minor importance in forestry. Some of the work done at the Experimental Station for Bird Protection at Seebach, in Thuringia, and by American observers, has already been referred to in this Journal (9). Bird investigation in British forests has received attention (3 and 7), but beyond tentative attempts to attract additional birds in the breeding season by means of nesting-boxes, little of a practical nature has yet been done.

Further scientific investigation into the ways of birds in woodland, and their numbers and distribution, what they eat, and how they can be attracted, is badly needed. In other words, Forest Ornithology should be put on the map. There is no need to dilate upon the damage caused by insects in our woods, and, prima

facie, it appears obvious that birds that habitually include insects in their daily, or seasonal, menus are an important adjunct to forest protection. The insect life consumed per head of the population of small birds is prodigious in quantity, especially during the nesting season, when so many species, some not true insectivores, feed their voracious nestlings entirely on an insect diet (2).

The number of British forest-dwelling birds is limited, and all types of forest are not equally attractive to bird life (9). In addition to suitability of habitat, a bird population requires food and water, appropriate nesting-places, quietude, and reasonable safety from foes (3 and 7). In dry woodland regular access to water may be a difficulty, and, in well-managed forest, the accommodation for hole-nesting birds is always scanty; hole-nesters, the tits in particular, are among the most assiduous searchers for insect life, including insects' eggs (2). For these reasons, and also because species naturally resorting to conifer forest are relatively few in number (9), it is always difficult to induce an *avifauna*, satisfactory as to numbers and variety, to settle in conifer plantations. And, among the conifers, the presence of insect-eaters is greatly to be desired.

With the foregoing general circumstances in view, a project was authorized by the Forestry Commissioners during the winter of 1941–2, having as its objects the attraction of more insect-eating birds to the hardwood inclosures in the Forest of Dean by providing artificially constructed nesting-boxes, and to ascertain, in due course, the effect an increased bird population may have on the periodic plagues of *Tortrix viridana*, *Cheimatobia brumata*, and other defoliators, which are troublesome in this forest, in common with many others of the English oakwoods. The experiment was put into effect on a small scale owing to the exigencies of war, under the direction of Mr. W. H. Guillebaud, Chief Research Officer, Forestry Commission, who has been assisted in the field by Mr. J. M. B. Brown, Research District Officer, and Mr. R. J. Matraves, Research Foreman. Messrs. Flynn and Sherrel, forest apprentices, have also helped. The three breeding-seasons which have elapsed have proved progressively successful in the attraction of resident and migratory breeding species, but, of course, it is yet too early to note any consequent effect upon insect pests.

The native *avifauna* of the Forest of Dean is peculiarly disappointing both as to species, numbers, and distribution, in spite of so much of the area being under hardwood crops, chiefly oak. Broadleaved and mixed woods usually provide optimum conditions for bird life, and the reasons for conspicuous poverty in this ancient forest are not altogether plain. The canopy in most of the oak plantations is not unduly close, and although some inclosures are relatively bare of underwood, there is an under-story of coppice and undergrowth in others, including bramble, &c., of the types attractive to warblers and other true insectivores. The population of magpies and jays is, however, excessive, carrion crows are fairly numerous, and the sparrow-hawk by no means unknown; this excess of predators no doubt has its effect on the numbers of small birds.

The experiment, which is limited to the attraction of hole-nesting species, was inaugurated in Nagshead inclosure in time for the 1942 breeding-season. A 37-acre block of oak was chosen as an average sample of the Dean Forest

oakwoods; the crop is of the 130/140 age class (about 70 trees to the acre) with sporadic undergrowth of holly, birch, beech, rowan, and chestnut; the ground flora includes bracken, bramble, and grasses. The area lies between the 380-feet and 550-feet contours, on a south-easterly slope, and is moderately well sheltered except along the western margin. There is no lack of control areas; similar oakwoods stand on three sides of the block, the boundary to the west being a broad ride with a 30-year-old mixed Scots pine and beech plantation beyond. The area suffers periodically from defoliators. There is a small brook at the eastern end of the block, apart from which there is no natural water. Eighty-four boxes were erected early in 1942, a number since increased to ninety-two. Included in the number of boxes originally put up were ten of larger construction, placed in an adjoining compartment, adjacent to Nagshead nursery, to which it is hoped to attract starlings to deal with chafer pests. This endeavour has not so far met with success, but the boxes have been well tenanted by smaller species. *En passant*, it may be observed that no relationship exists between the breeding-places adopted by starlings and the *loci* of their undesirable autumnal and winter roosts.

A second area (approximately 35 acres) was marked out in the winter of 1942–3 in Perch inclosure, some 2 miles to the north of Nagshead, on the north and south-east faces of rising ground between the 400-feet and 550-feet contours. The crop is oak of approximately the same age-class as in Nagshead, but with some large beech and chestnut. In this case also the adjacent woods provide ample controls. The undergrowth is patchy and occasionally dense; the ground flora is abundant except beneath the beeches and where the coppice is dense. Seventy boxes have so far been put up in this block, making a total of 162 in all.

According to the experience at Seebach (5 and 8) two occupied boxes per acre are required to secure satisfactory protection against caterpillar damage. To secure occupation at this rate the aim of the present experiment is to provide three boxes per acre, i.e. at roughly 40 yards spacing. The type of box used is a modification of the Westphalian nesting-box (1 and 4), as illustrated (Text-fig. 1), from which it will be noted that, as a protection against weather, the box is attached to a fixing lath at an angle, in order to tilt it so that the entrance-hole points slightly towards the ground when the lath is fixed to the tree. To fix the box the lath is screwed to the tree in a vertical position at a height of 10 to 12 feet from the ground so that the orifice faces south-east. A twig or branch nearby is useful as a perching-place (1). The more open the position the better, and if the bole of the tree is obscured by tall coppice, the underwood should be cut away. It is advisable to avoid trees that are easily climbable. Boxes intended to attract starlings are made slightly larger over all, with an entrance-hole 2 inches in diameter, as opposed to 1·25 inches for the smaller birds.

The main features of the box adopted are the wide, overhanging lid; the hinged front which is opened for inspection from below simply by unfastening one brass screw; and the fixing lath, secured to the right-hand side of the box at an angle of 5° to 10° from the vertical (1). The material used is rough oak or larch slabwood from the sawbench, edged, and with bark attached. Nesting-boxes

require careful construction, and, in particular, all joints must be true and draught-proof. In present conditions the cost per box works out at six shillings. More precise constructional details are given as an Appendix.

The record of boxes effectively occupied by nesting pairs is stated in the table below:

37-acre Block in Nagshead Inclosure

Breeding season	*Pied flycatcher*	*Great tit*	*Blue tit*	*Coal tit*	*Red-start*	*Nut-hatch*	*Forsaken or robbed*	*Boxes missing*	*Unoccu-pied*	*Total*	*% of success*
1942	14	9	2	1	1	..	7	..	40	74	36%
1943	24	19	8	..	1	1	1	5	23	82	65%
1944	33	18	12	..	2	1	5	3	8	82	80%
				[Large (starling) boxes]							
1942	1	3	..	..	1	..	1*	..	4	10	60%
1943	2	3	..	..	2	1	..	..	2	10	80%
1944	3	1	..	..	1	1	..	..	4	10	60%

* A forsaken nest of moss, lined wool, contained ten white eggs, provisionally identified as a Wryneck.

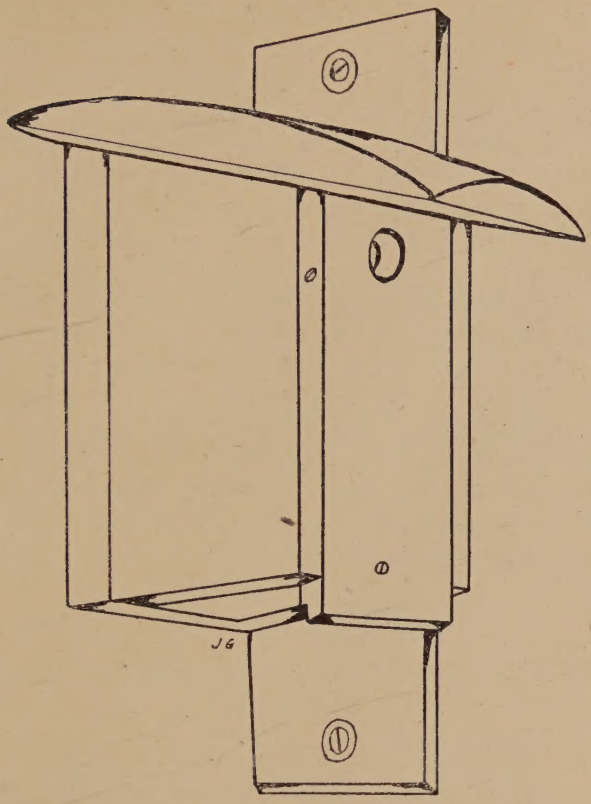
35-acre Block in Perch Inclosure

Breeding season	*Pied flycatcher*	*Great tit*	*Blue tit*	*Red-start*	*Nut-hatch*	*Forsaken or robbed*	*Boxes missing*	*Unoccu-pied*	*Total*	*% of success*
1943	22	17	8	..	1	2	..	20	70	69%
1944	29	15	9	..	1	8	..	8	70	77%

Thus, in 1944, 126 boxes were successfully occupied out of a total of 162 boxes in the two blocks, a percentage of 75. Examinations of the contents of the boxes have been made in the middle of the nesting period and again at the end (July–August). In future, to avoid disturbance, it is proposed to make binocular inspections in the last week of May and again in the second week of June. The first inspection is designed to catch the tits in the act of feeding their young, and the second similarly to observe the pied flycatchers and redstarts. In the last week of July the boxes will be opened and examined. The dates must be taken as approximate, and will again be reviewed in the light of experience. Mid-season examinations present the difficulty of disturbance, and in some cases the birds readily forsake their nests. On the other hand, without careful intermediate observation it is impossible to say whether more than one brood per box has been brought off. It is clear that at least a second nidification occurs in some of the boxes in course of the season and not always by the same species. Short of repeated openings of the boxes for examination, it is not always possible to detect these cases except where superimposed nests are found when the boxes are finally opened; consequently it is probable that the results tabulated do not record the full total of occupations or of broods successfully brought off. It is hoped that the proposed binocular observations will go far to correct this, possibly important, discrepancy.

There have been some intruders. Two boxes housed wild bees' nests in 1943,

— NESTING BOX. —



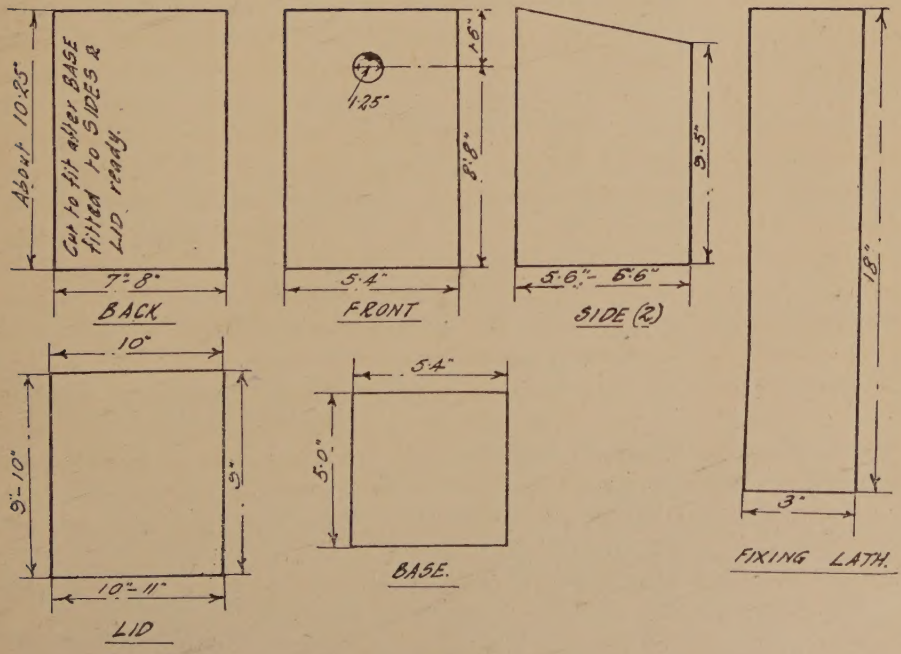


FIG. 1.

and another was similarly occupied in 1944, while long-tailed field mice were bolted from two boxes in 1944. During the three seasons twelve boxes have had their holes bevelled off or enlarged by great or lesser spotted woodpeckers, none of which has yet attempted to take possession for breeding purposes. The joints of the boxes occupied by nuthatches have been covered with characteristic mud plastering. For nesting materials the pied flycatchers and redstarts use dry grass and leaves; great tits make their nest of moss with a wool lining, the cup being large and placed centrally in the box; blue tits' nests, also of moss, are lined with wool and feathers and have a smaller cup which is located in one of the rear corners of the box. Nuthatches use fibre, bark, and dead wood, almost filling the box. Tits' nests are clean and tidy with few food fragments, but those of the pied flycatcher contain excreta and yield numerous remnants of nestling food (1).

Food fragments, from boxes from which broods have flown, have been collected each season, and samples have been submitted to the British Museum (Natural History) for examination. The insects identified are classified in the following schedules, and the Forestry Commissioners are indebted to Mr. N. B. Kinnear, Keeper of Ornithology, and Dr. K. G. Blair, for examining and classifying the material submitted:

Specimens Identified

1. *Insects from Nests of Pied Flycatcher, July 1942, N. B. Kinnear and K. G. Blair.*

Lepidoptera	*Hepialus velleda*	1 ♀
	Smaller moth	1 indeterminable
	Himera pennaria	1 full-grown larva.
	Taeniscampa stabilis (?)	1 nearly full-grown larva.
	Smaller larvae	2 indeterminable.
	Tortricidae	2 pupae.
Coleoptera	*Phyllopertha horticola*	3
Elateridae	*Athous haemorrhoidalis*	7
,,	*Melanotus rufipes*	1
,,	*Agriotes acuminatus*	1
Cantharidae	*Podabous alpinus*	5 (warning type of coloration and possessing stink-glands).
,,	*Cantharis spp.*	7
,,	*Haplocnemus impressus*	1
,,	*Leiopus nebulosus*	5
Rhyncophora	*Phyllobius maculicornis*	1
,,	*Polydrusus cervinus*	1
,,	*Strophosomus melanogrammus*	4
Cerambyscidae	*Strangalis maculata*	1 (black and yellow, but *Longicoras* generally acceptable).
Hymenoptera	*Rhogogaster viridis*	1
Diptera	*Bibio marci*	8 ♂, 6 ♀.
	Xylophagus ater	1 ♀, generally rare.
	Machimus atricapillus?	4
	Muscidae (large spp.*)	11
	,,	1 puparium.

Neuroptera	*Raphidia notata*	6
Hemiptera	*Pentatoma rufipes*	3 adults, 2 nymphs (protected by stink-glands).
	Calocoris ochromelas	3 (black and yellow coloration).
	Triecphora vulnerata	2 (warning colours, black with red spots).
Orthoptera	*Forficula auricularia*	1 ♀.
Spiders	3 fairly large	..
Woodlice	5	..
Millipeds (Julus)	1	..

NOTES. *The large size of the prey is striking, with complete lack of very small species.

The large proportion of 'distasteful' species, both those with a 'warning' type of coloration and those protected by strong stink-glands. Further, these were not represented by single specimens but were taken repeatedly.

A high proportion of captures must have been taken off foliage; some probably from behind loose bark on trees or among old ivy; and others likely to have been captured in flight, the Diptera, especially *Bibio*, are perhaps most likely, but these may have been seized when settled on herbage.

Muscidae (det. Coe)

Echinomyia fera	1
Ernestia nielseni	6
Polietes lardaria	2
Sarcophaga carnaria	2

2. *Preliminary identification of Insect Remains from Pied Flycatchers' nests, J. M. B. Brown, 1942.*

(1) *Tortrix viridana* (adults) . . . . . in 6 nests
(2) *Phyllopertha horticola* (adults) . . . . . in 2 „
(3) Click-beetles (Elsteridae) (chiefly *Athous haemorrhoidalis*) . . . . in 4 „
(4) Cantharid beetles . . . . . in about 5 „
(5) Leaf and shoot weevils . . . . . in 2 „
(6) *Bibio Marci* (Dipt.) . . . . . in 5 „
(7) Large Muscid flies . . . . . in about 7 „
(8) *Raphidia notata* (Brown lacewing) . . . . . in 4 „
(9) *Hemiptera* (Bugs—chiefly the large greenish *Pentatoma* and the red and black *Triecphora vulnerata*) . . . . . in 5 „
(10) Spiders and woodlice (which may, like the earwigs, have entered through cracks) in 4 „

The nest in box 69, which appeared to be especially well stocked, was examined in more detail and the insects sorted as follows:

Lepidoptera	33	(1 imago and 28 pupae of *Tortrix viridana*; 3 Tortricid and 1 Geometrid larvae)
Coleoptera	22	(7 Click-beetles; 6 Longicorn adults; 4 weevils; 1 bark-beetle; 1 *Phyllopertha*)
Diptera	4	(1 *Bibio*; 2 Muscids; 1 ?)
Neuroptera	3	(3 *Raphidia notata*)
Hemiptera	3	(1 *Pentatoma rufipes*; 2 *Calorcoris ochromelas*)
Miscellaneous	8	(1 earwig, 1 millipede, 2 spiders, 4 woodlice)

In contrast with this, the great tits' nests yielded very little. Pupae of *T. viridana* were taken from 3 (1 each) and besides these only 1 *Bibio* and 1 Muscid fly were collected. Against this, the blue tits' nests yielded 13 *Tortrix viridana* pupae and 1 larva and 1 pupa of other Tortricidae. In the redstart's nest were found 3 *Tortrix viridana* pupae, 1 *Raphidia*, 1 *Bibio*, 1 millipede, and fragments of a grasshopper.

3. *List of Insect remains submitted to N. B. Kinnear for identification, August 1944*

	No. of specimens
COLEOPTERA	
Carabidae	
Abax sp. (larva)—P.F., N.	1
Silphidae	
Silpha (*Xylodrepa*) *quadripunctata* L.—N., N.	2
Silpha (*Xylodrepa*) *quadripunctata* L. (larva)—B.T., N.	1
Silpha sp. (larva)—P.F., N.	1
Telephordae	
Denticollis linearis L.—P.F., P.	1
Cantharis nigricans Mull.—P.F., P.	2
Athous haemorrhoidalis F.—P.F., N.	1
Rutelidae	
Phyllopertha horticola L.—P.F., P.	3
Phyllopertha horticola L.—	—
Tenebrionidae	
Helops laevioctostriatus Gze.—P.F., P.	1
HYMENOPTERA	
Apidae	
Bombus hortorum L.—B.T., N.	1
LEPIDOPTERA	
Agrotidae	
Amphipyra pyramides L.—B.T., N.	1
DIPTERA	
Syrphidae	
Eristalis pertinax Scop.—G.T., N.	1
Calliphoridae	
Lucilia sp. (?) (1 freshly hatched adult, 1 puparium)—G.T., N.	2
Gen. and sp.? (2 puperis)—G.T., N.	2
Protocalliphora coerulia R.-D.—B.T., P.	1
Protocalliphora coerulia R.-D.—B.T., N.	2
Protocalliphora coerulia R.-D.—P.F., P.	1
Protocalliphora coerulia R.-D.—P.F., N.	1
? *Sarcophaga* sp.—B.T., P.	1
Calliphora vomitoria L.—B.T., N.	1
Calliphora vomitoria L.—P.F., N.	1
Tachinidae	
Echinomyia fera L.—P.F., N.	1
ISOPODA (Woodlice)	
Oniscidae	
Oniscus asellus L. (the 'common slater')—P.F., N.	2
Oniscus asellus L.—P.F., R.	1

Note re abbreviations mentioned above.

B.T., P. = Blue Tit, Perch.
B.T., N. = Blue Tit, Nagshead.
G.T., N. = Great Tit, Nagshead.
P.F., N. = Pied Flycatcher, Nagshead.
P.F., P. = Pied Flycatcher, Perch.
N., N. = Nuthatch, Nagshead.

The relative proportions of the different species using the boxes have not varied to any great extent in any year, either in Nagshead or Perch. Pied flycatchers, not locally known as breeders in previous years, have predominated from the first. The project is not represented as a complete experiment by any means, and it is recognized that there are a number of details yet to be attended to before the work can be considered fully systematized.

It is recognized that nesting-boxes are only a single item in a comprehensive scheme of bird attraction, and that provision is also desirable for the encouragement of soft-billed, forest-dwelling species, for which undergrowth, other than coppice, open spaces, and drinking-pools are the necessary incentives. It may also be argued that, in the absence of a preliminary local census, the results obtained lose part of their value; however, a bird census requires the co-operation of ornithologists, who, in war-time, are otherwise employed.

A rough census was taken in 1942, on the Nagshead block, based on careful observations made during the inspections, particulars of which are set out below. Besides this there are ample control areas in the adjacent woodland for points of comparison in future years.

Census of Birds, Nagshead Block, May 1942 (Brown)

Species	*Probable pairs*	*Nests found*	*Nests in boxes*	*Remarks*
Great tit	10	9	9	..
Blue tit	6	3	2	..
Coal tit	2	1	1	..
Marsh tit	1 (?)	..	..	Nest in tree by Box 3.
Long-tailed tit	2	1	..	..
Wren	3	..	..	..
Goldcrest	2	..	..	..
Chaffinch	3	..	..	..
Jay	1	1	..	..
Great spotted woodpecker	1	1	..	..
Wood pigeon	1	1	..	..
Blackbird	2	..	..	..
Thrush	1	..	..	..
Robin	4	..	..	..
Redstart	3	1	1	..
Pied flycatcher	14	14	14	..
Chiff-chaff	2	..	..	..
Willow warbler	1	..	..	..
Wood wren	2	..	..	Probably unmated.
Garden warbler	2	1	..	Nest destroyed.
Brown owl	1	..	..	..
Total pairs	64	33	27	

Other birds seen : pheasant (1), nuthatch (1), sparrow-hawk (1).

The experiment will be continued and, as opportunity offers, extended. In the meantime the missing and damaged boxes are being replaced or repaired each year. Annual repairs and replacements each season should be completed by

1 March. A good many boxes are found damaged or with loose opening screws, or none at all, possibly the result of winter mischief by boys. Pillaging is a danger against which appropriate steps will have to be undertaken if it occurs systematically. The activities of wild depredators must also be observed, as a dead adult tit, dead flycatcher broods, and pierced and sucked eggs have been found in a few of the boxes at the end-of-season examinations. Grey squirrels have increased considerably in the Forest of Dean in the last few years and must also be kept under observation in connexion with the experiment, although no indication has so far been noted that these animals are causing trouble.

So far as it has gone this experiment shows that an efficient type of nesting-box has been devised, and that it is possible to establish a population of nesting-birds of the order of two families per acre in this type of woodland by the use of appropriate nesting-boxes. When the war is over and labour and materials are easier to obtain, it is hoped also to extend the experiment to some of the young conifer areas planted by the Forestry Commission, especially to pine plantations which are liable to suffer seriously from insect pests such as the pine shoot moth and the pine sawfly.

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APPENDIX

CONSTRUCTIONAL AND OTHER NOTES ON THE NESTING-BOXES

Materials used. The material from which the boxes are made is oak slabbing. The thickness of the parts will depend largely on the slabs themselves, but should nowhere be less than ½ in. Experience has shown that the re-sawing of slabs to get thinner and so lighter parts adds greatly to the cost of the boxes.

Base. 5·4 in. × 5·0 in. All four edges should be planed true and square. Drill three ¼-in. drainage-holes, evenly spaced.

Sides. Between 5·6 in. and 6·6 in. wide. Sloping from 9·5 in. high at front to 10·25 in. at back. Attach to base by two 2½ in. nails each side. Plane true the two edges to which the back will be nailed.

Back. Between 6·6 in. and 7·6 in. wide. The top edge must slope upwards in a continuation of the slope on the side pieces. To cut this slope the sides should be nailed on to the back

piece (six 2½-in. nails) and the side will guide the saw. Plane the three edges to which the top will be nailed.

Lid. About 9½ in. × 11 in. Allow a small overhang at back and on the right side. The overhang at the front should not be less than 2½ in. Attach by four 3-in. nails.

Front. 10·4 in. long and a loose fit between the sides. Hole is 1¼ in. diameter, 1·6 in. from top. Bevel the front top edge to allow clearance when opening. Secure and also hinge by two 2½-in. nails level with the centre of the hole. Put one *brass* screw (recessed if necessary) into the centre of the front. The screw should not be screwed right home when the box is erected.

Inside Battens. Two 6 in. long, cut from plasterer's laths. Must be parallel and level with the front of the base. Secure each by two 1-in. nails to the inner face of each side to form a stop to the hinged front of the box.

Fixing Lath. 18 in. long. Cut a small recess to fit around the lid of the box and secure at the correct angle (15° from the vertical plane of the lath) by three steel screws. Two ¼-in. holes should be drilled in it for nailing it to the tree. The lath is made from 3 in. × 1 in. oak rail, cut die square. The effect of the angle at which the box is fixed to the lath is to tilt the box so that the orifice points towards the ground when the lath is fixed vertically to the tree. This gives additional protection against the rain driving in. The accompanying sketch (Fig. 1) does not give an adequate idea of the sloping position of the box relative to the lath.

Method of Fixing to the Tree. The lath to which the box is attached is fixed in a vertical position to a suitable tree on its north-east side, so that the orifice of the box faces south-east. The height above the ground should be 10–12 feet.

Number of Boxes per acre. Three per acre, i.e. roughly 40 yards apart. Each box should be given a number painted with large figures on the lath. A large cross in white paint should be painted on the tree at about breast height so that the boxed tree can be picked out from a distance.

Supplementary Specification for Starling Boxes

Base. 7·9 in. × 6·7 in. with three drainage holes.
Sides. 10·8 in. back, 9·1 in. front, 8·7 in. wide.
Back. 11·0 in. × 8·3 in.
Lid. 13·8 in. × 9·8 in.
Front. 9·8 in. × 6·7 in. Hole is 2 in. in diameter.
Lath. As for Tit Boxes.

Note. In the Forest of Dean it was found very difficult to pick out slabbing of sufficient width to provide the material required by the above specification, and the boxes were excessively heavy. It may be necessary in practice to construct the starling boxes, in part at least, from sawn timber.

SOME IMPRESSIONS OF PRIVATE FORESTRY

BY JAMES MACDONALD

IT may interest readers of this Journal to hear of some of the things which a Forest Officer has learned during the war while serving in the Department which is responsible for the production of home-grown timber. Although nothing can yet be said about its activities, it is no secret that that Department was partly staffed by officers of the Forestry Commission who, at the beginning of the war, were transferred to it from their normal duties, and who, very quickly, had to take their share in building up a new organization. And as the organization grew so did its problems increase. The solution of each problem as it arose, the testing and training of inexperienced men and women, the desperate improvisations which were sometimes needed to overcome urgent difficulties, added to the uncertainties and the excitements of the days and nights of 1940 and 1941, made life then an exhilarating affair, but lent an effect of anticlimax to the subsequent years when the machine was running more smoothly, and when the difficulties and problems had begun to lose their novelty. Although this work in time of war has taken us away from our usual occupation, yet the removal has not been to too great a distance. We are still in the woods and we have seen them from a different point of view. In other ways, too, we have added largely to our experience, and we have been able to look more deeply than would have been possible in other circumstances into the nature of some of the problems which will be waiting for foresters to solve when the war is over.

As one of the officers seconded for work in timber production, I found that the new activities called at once for a drastic alteration in one's outlook. The woodlands, the plantations, which by training, by experience, almost by instinct, one had come to regard as something to be tended and protected and improved, became almost overnight the objects of an entirely different scrutiny. One could no longer go into a wood with the eye of a forester, looking for good points to note, for faults to be remedied; one went instead to find out whether it would give the produce which was needed. The careful husbandman had perforce to become the butcher. To begin with, an attempt was made to conserve the middle-aged classes of timber and to bear lightly on stands of all ages that were well managed, but it soon became obvious that the demands were so great and the need so imperative that those well-meant attempts to save what was worth keeping had of necessity to be abandoned. It has happily been possible to preserve many crops of particular interest silviculturally, but many have been lost, in some cases because we were unaware of their existence until it was too late to save them. After five years of this work the sensibilities tend to become blunted, but enough remains of the professional conscience to cause twinges of regret at the sight of a promising crop coming down. It would have been nice if, for example, the demand for round mining timber

could have been met by thinning, but the war came many years too soon for that. Yet there are, or were until recently, people who believed that that was possible. They have been living in a world of illusions.

When war broke out I was stationed at Cambridge, and I remained there in my old Division on Timber Production for rather more than two years. That division comprised four of the Eastern counties and one in the north Midlands. Then I moved to Nottingham, where I had to deal with woodlands in two other Midland counties, which were unfamiliar to me, and in the East and West Ridings of Yorkshire. After two years there I was moved to Aberdeen, where, in the north-east of Scotland, I was able to see the effect of this war on the extensive woodland areas of that district. What I have to say in the following pages has been derived from my experiences in those parts of the country. They may be typical of the rest of Great Britain or they may not. Timber production has brought us foresters into contact with private estate forestry in such a way as to give us a much clearer picture of its good points, its failings, and its difficulties. It has also given us first-rate experience of the utilization of produce and has brought us into touch with the home-grown timber trade, which has undoubtedly a part to play in whatever developments take place in British forestry in the future. It was mainly because these contacts seemed to me to be of some importance that I decided to record a few of my impressions, in the hope that they might be of interest to other foresters.

The first thing we had to do when war began was to find timber, and finding the timber raised the first of our difficulties. We knew quite accurately what timber was available in the State forests and at once we set a large gang of men to work felling such of it as was then considered suitable. But the timber available in the State forests of which I had had charge did not amount in all to more than a relatively small quantity, and the obvious source of supply was the large woodland area in private ownership. Our initial difficulty in dealing with those private woodlands was that we did not know what they contained. The Census of Woodlands which the Forestry Commission began shortly before the war covered only part of the division, and that part the least important. The estates, or most of them, did not know themselves accurately what they possessed in the form of timber, and I myself, to make matters worse, found to my horror that I knew almost nothing about the private woodlands in my division.

My case may not have been typical, but I found, before the war, that all my time was taken up by the management of the State properties which were in my charge. Among these were between 50,000 and 60,000 acres of plantations, scattered over five counties between the Essex border and the Humber, and, in addition, there were considerable areas of agricultural land, most of it marginal, which added much to the burdens of management. A forest officer within his own district should be as familiar with privately owned woodlands as he is with the State plantations, but this, as I have suggested, was not always possible, and there is little doubt that some of the misunderstandings which have lately arisen have resulted from this cause. This, in every way, is unfortunate because both are working to the same end and their efforts ought to be complementary. There

is much that an officer of the State service can learn from a study of the private woodlands around him; at the same time, private owners, their agents, and foresters would do well to become familiar with the State forests, for there they would find many things which, if they adopted them, might greatly improve their own practice. On the other hand, if one takes the long view, the Forestry Commissioners were undoubtedly right in concentrating their effort on the establishment of new State plantations, for in no other way could they have made so much of the resources at their disposal. Their misfortune has been that this war has come too soon. If it had come 15 or 20 years later, there would have been no question. The facts would have shown how right was their policy.

Five years' work, mostly in private woodlands, has left me with the feeling that the purely technical problems of bringing them back into good condition have been under-estimated in all the discussions which have taken place on this subject. So far as my experience goes, the condition of estate woodlands in England is poor, and, indeed, in the counties with which I am familiar, the well-managed woodland properties are really very few in number In Scotland the condition seems to be much better, but in fairness to those south of the Tweed it must be pointed out that the problems of management in Scotland are very much simpler than they are in England. In Scotland there are, it is true, here and there, complex problems of establishment, but once the crops are established, their management is essentially a simple matter. There is nothing in Scotland to compare, for difficulty, with the management of woodlands on the heavy clay soils of the Midlands and the south of England. The principal fault in the Scottish woodlands, which are nearly all coniferous, is lack of thinning, but that has been the result of high transport charges to the centres of consumption.

Why is it that the condition of many of the privately owned woodlands in England is so poor? It is difficult to answer the question satisfactorily. One could mention the depression that settled on all rural activities, farming as well as forestry, for so many years, but that depression hit Scotland as hard as it hit England, and yet the Scottish woodlands have not suffered in the same way. It is the same with high taxation which is by some people accounted the principal cause. This has borne on the Scottish landowner as heavily as on the English. It is true that the types of woodland commonest in England suffer more quickly and more severely from neglect, yet, on the other hand, there is less inducement to neglect the woods in England, even in bad times, because there are markets to be had for produce in that country of a kind which we never dream of in Scotland. One advantage which Scotland possesses is the relatively large size of the woodland estates. Where there are large areas of woodland, playing an important part in the economy of the estate, the whole standing of forestry is raised. Skilled foresters can be employed and given the opportunity of displaying their talents, the management is more conscious of the importance of forestry and the owner himself, more often than not, becomes a keen forester. The last is an important point, because I think that one of the main troubles from which private forestry suffers in some parts of England is the apathy of landowners, and until this is dispelled I cannot see much hope of secure progress. I do not

know of any well-managed woodlands of which the owner is not a keen forester, but I know of several estates that employ men who, by any standard, could be described as skilled foresters and yet on which the forestry is really bad. A skilled forester will not give you good forestry if his efforts are rewarded with indifference or hostility.

But in the background of all the troubles lurks the figure of the keeper. There is no doubt that the extensive preservation of game is, more than anything else, the cause of much of the bad forestry in England, and its effects are worst on the small estates where every wood may have to be taken into account by the gamekeeper. It has been said that the more pheasants there are the worse is the forestry, and in this saying there is an element of truth which may hint at another reason why things in Scotland are better than they are farther south. There seems to be a tendency, in discussing the future of private woodlands, to avoid the difficult subject of the relationship between forestry and sport. This surely is to be deplored because the success of any scheme for woodland improvement must depend on a correct adjustment of the two forms of activity. It has been said by many people, and in a general way it is true, that forestry and sport can be combined successfully. But are we sure that first-class forestry can be carried out without detriment to that form of sport which commands the highest rentals? On the one hand we have the prime need in the immediate future to improve our woodlands; on the other hand, we must not forget that to many estates the income from sporting is an important consideration. It is possible, at least to begin with, that both sides may have to give way a little before an agreed line can be followed.

There has been much talk about the need for trained foresters on private estates and with that everyone is in agreement. But there is just as much to be said for the training of keepers. On most estates, in normal times, the gamekeeper occupies an important position and his requirements, at certain seasons of the year, impinge hard on the activities of others and especially on the forester's. It is all the more important, therefore, that the keepers should be trained in their own job and educated to understand all its implications. Amongst keepers there are many capable men and some who are educated, but all too often one encounters the man who seems to have no more qualification than a good eye and a roughly gathered and slightly muddled knowledge of natural history. A keeper's job is one which is not easy to supervise and he must of necessity be left very much to work by himself. In such circumstances, a man is apt to become slack and inefficient unless he has had developed in him by training high standards of technical competence. After the war there will probably not be enough trained foresters to meet the requirements, and, in the emergency, something might be done on small estates to combine the offices of forester and keeper in one man who has had some training both in forestry and game preserving. This is not the best solution, but it would mark an advance on the present system which is apt to have no forester or forestry at all.

It has already been stated that the standard of forestry is low and the condition of the woodlands poor in many parts of the country and especially in some of the English counties, and some of the weaknesses which catch the eye of a trained forester are discussed in the following paragraphs. Some of these weaknesses are

the result of forces over which the owners have had no control whatever, but many are the consequence of the lack of skilled technical guidance and some are the result of mere apathy.

1. The first thing that attracted attention was the poor stocking of most of the older broad-leaved woods in England. There are many districts in central and eastern England where it is exceptional to find a broad-leaved crop with more than 1,000 cubic feet of timber to the acre, and a very large number have less than 750 cubic feet per acre. As most of these woodlands should be carrying at least 2,000 cubic feet, this means that there are very large areas of forest land not at all fully productive. This has meant a heavy loss to the country at a time when every woodland acre should be producing as much timber as possible. How has this come about? There are various reasons.

(*a*) The most important is the disastrous practice which has for long been common and which reached the height of its intensity in the years between the wars—the practice of selective felling. The practice is essentially a manifestation of economic depression. Times are bad and the owner needs money. He has trees which he can sell, but the home timber merchant whose trade is also depressed can risk buying only the very best trees or trees for which he has a special market at the time. So they go through the woods and pick out the trees which are wanted, leaving the unwanted and the inferior trees to cover the ground as best they may and with little hope of growing any bigger. But this selective felling is often practised when it does not have the justification of hard necessity, and it has even persisted throughout the war when there has been a market for almost every kind of produce. I can think of hundreds of acres of oak-wood from which all the trees of more than 12-inch quarter girth have been removed in this way, leaving behind small trees which, in the original unbroken crop, were dominated and suppressed members. And oak-trees which, at a hundred years of age or more, are less than 12 inches in quarter girth, have a poor prospect in front of them. It is to be hoped that, after the war, this method of exploitation will be brought under control, because if it is permitted to continue the results will be extremely grave.

(*b*) The break-down of old silvicultural systems is also responsible for some of the poorly stocked hardwood areas. There is something to be said for the old system of coppice-with-standards as a method of management on heavy, weed-infested soils, and it is in many ways a pity that this system has broken down. Its collapse, in many districts, has littered the country-side with derelict areas in which the few surviving trees stand up over a mass of thorns and other shrubs which have smothered the enfeebled shoots from the old coppice-stools. These derelict blocks of old coppice-with-standards, in the aggregate, account for a large part of the non-productive woodland areas in private ownership. Elsewhere, the remains of coppice woods of oak, grown originally for their bark, still remain, although a good many woods of this kind have been felled during the war. In many cases these woods also are carrying much less timber than they are capable of producing.

(*c*) Faulty choice of species in the past has been responsible, but to a much

smaller degree, for woodlands which are now unproductive. One finds oak, for example, planted on quite a large scale on sites where from the beginning it had little prospect of growing to any size. Such plantations remain to this day full of small stunted trees, producing little and promising less.

The war has affected these areas of low stocking and production in two ways. It has added to their number in consequence of the selective felling which has continued, but at the same time it has permitted the clear-felling of a certain number and it is probable that, by the end of hostilities, the total area of this kind of woodland may have been slightly reduced. But it will still remain in acreage sufficiently large to pose a very difficult problem to foresters in post-war years. These poorly stocked woods are almost wholly confined to England.

2. The second feature that strikes the observer is the extraordinary arrangement of age classes met with in the woods on most private estates. It is difficult to think of even one large estate where there is a reasonably good series of plantations of different ages: young plantations, pole woods, middle-aged woods, and mature timber; and the absence of an orderly arrangement of this kind leads, in normal times of peace, to difficulties in the organization of marketing, and, in war-time, to marked inequalities of sacrifice as between one owner and another. There are several reasons for this:

(*a*) It is due in many cases to changes, over a period, of the policy of the estate with respect to planting. One owner may have been a keen forester and may have planted large areas. His successor, with no interest in forestry, may have done nothing to add to his holdings of woodland, and if his tenure of the property was a lengthy one, a large gap would be caused in the succession of the age classes. He in turn may have been succeeded by a man like himself or by a planter, and the irregularity in the management would persist. The result of this discontinuity in policy can be seen on many estates which have been in the ownership of the same family over a lengthy period of time. But its effects endure and, in some cases, make proper woodland management very difficult.

(*b*) The break-up of large estates into smaller properties has tended to exaggerate this irregularity. A good arrangement of ages on a large estate would certainly be completely upset if that property were broken up. One finds everywhere examples of the curious results of this process.

(*c*) In all the discussions about private forestry, enough weight has not been given to the heavy fellings of last war as a cause of some of the ills from which it suffers now, because the bad distribution of ages among the woods on most estates was greatly intensified by the removal, for war purposes, of large quantities of timber between 1914 and 1919. There are, for example, parts of the West Riding and parts of Lincolnshire from which all the mature timber was removed at that time, with unfortunate results for the present and for the future, and other parts of the country suffered a similar experience. And the felling which has been going on throughout this war has made matters worse. This feature seems to me to be of some importance, because if private forestry is to prosper it must have markets for its produce. But to get markets and to keep them, a regular flow of produce must be guaranteed, and this, because of the age distribution of the woods, most

estates cannot do. It is, therefore, clear that some form of co-operation among the owners of neighbouring estates will be needed in the future if markets for produce are to be found and retained.

3. A good deal has been said earlier about the older woods in which the stocking is abnormally low, but, when young woods are looked at, it is too often found that they have, not too few, but too many trees. Thinning is very often badly neglected. As has already been pointed out, reasons of economics have in Scotland prevented owners from disposing of their produce and thinning has, in consequence, been neglected, but these reasons do not work with the same force over most of England. There has, all too often, been a reluctance to undertake this necessary work, a reluctance which it is difficult to account for when one knows that the produce would have paid at least for the cost of the operation. One finds, too, quite frequently, blown trees left lying unattended to and harbouring beetles which breed and go out to damage other trees, and in some cases one has found that though thinnings were marked and felled they have been left lying on the ground, and that in districts where the local markets were quite good. Many estates thin their woods well, but there are far too many which do not, and the indifference to thinning is the worst thing I have seen in the private woodlands which I have visited.

4. Another matter which is very often neglected in private woodlands is drainage. When drains are neglected, trees are often wind-blown, and if the drainage system breaks down on sites which are naturally wet, the result may be a marked slowing down of the growth and a die-back of the branches. Generally, it is found that wherever drainage is necessary a reasonably good, sometimes a very good, system is put in to begin with, but this is very often not maintained as it should be, and, if selective fellings have been taking place, it is usually wrecked altogether. In some instances the war has led to an improvement, because the intensive drainage now being carried out on agricultural land has had a beneficial effect on plantations standing in the midst of it. The maintenance of drains can be an expensive item if the work is too long neglected, but if attention is given at the right time the cost of upkeep need not be high.

5. There are far too many pure crops of broad-leaved species, and one outstanding feature, as Professor Steven recently pointed out, is the absence, from much of our woodland, of shade-bearing species. My own view is that they have been discouraged in the interests of game because, without them, there is ample cover on the ground under the light-demanding species, whereas if they are present the floor is bare. Their absence has undoubtedly had bad silvicultural results and the luxuriant weed growth, which springs up in the absence of shade-bearers on most fertile soils, is in some ways more inimical to natural regeneration than the rabbit.

There is something wrong, too, with the mixtures of species which we see nowadays, and, to judge by results, our forefathers were more successful with their mixtures than we appear to be. The art of raising successful mixtures seems, to some extent, to be lost, and there is scope for experimental work to find a way of recapturing it.

This recital of the state of private forestry in this country no doubt makes depressing reading, but it is all true. It is only right, however, to point out that many of the present troubles have been brought about by the tremendous demands which have been made upon it by two great wars within a quarter of a century, and it is a tribute to those who planted that the stocks of timber, which they laid down, have proved sufficient to get the country, on two occasions, out of a very tight corner. And the owners of the timber, who have met the repeated demands for more and more, deserve the thanks of the country for the way in which they have come forward to help it.

Nevertheless the problem remains. The job of repairing and renewing the private woodlands is a big one, and it will require all the skill and ingenuity of foresters to make a success of it. The nature of the problem will to some extent depend on how much longer the war lasts, and what further demands are made on the estates for timber, but there will be at least the following work to do.

(*a*) *Thinning of young and middle-aged plantations and of older woods which are capable of improvement.* This is the work which should be given priority, because it is best to make sure that your existing woods are in good order before you add to them by planting.

(*b*) *Formation of new plantations.* In coniferous areas this will have to be delayed until all danger of attack by weevil has passed. In hardwood areas it should be dealt with as rapidly as possible before weed growth and coppice shoots become too strong. The removal of lop and top lying on hardwood areas may be laborious and costly.

(*c*) *Treatment of poorly stocked old woodlands.* When these can be clear-felled and replanted, this should be done, but there may be many cases in which this is undesirable and methods of suitable treatment will require to be worked out.

Experimental work is obviously required in certain directions. Much has already been done on the establishment of hardwood plantations, and the results might be made available to the public. Possible mixtures of species, suitable for planting on private estates, should be tested by experiment, and work should be started as soon as possible on the restoration of the poorly stocked hardwood areas.

As I go round the country, people often talk to me about the future of private forestry, and some of them seem surprised that an officer of the State service should be interested in it or concerned about its future. They all hope that the Government will do something to help them, and they seem to be prepared to accept some kind of direction, but they all add the expression of another hope that this will not bring a fresh 'horde of officials' down upon them. This phrase puzzles me, because I can never see in what way a horde of government officials is worse than a horde, say, of land-agents or solicitors, but to many minds it seems charged with a peculiar malignancy which the official himself finds hard to understand. But it does represent a genuine and not unreasonable desire that any control, which may have to be imposed, should be exercised in an intelligent and understanding way by men who know the job and appreciate its difficulties. Some of them say that, in the future, the private owner will have no chance to sell his

produce because of the enormous quantities that will be coming on the market from the Forestry Commission plantations. In this, I think they are quite wrong who say so, because the disposal of large quantities of produce from State forests will introduce those elements of stability and continuity which have hitherto been lacking in the marketing of home-grown timber.

The experience of the war has shown that the controls which have been most successful are those which have taken most fully into their confidence those with whom they have had to deal. In this way, they secured co-operation instead of the hostility which is apt to arise when there is no understanding. After the war, private forestry and State forestry will have to work side by side with a common object, and, if there is to be regulation or direction or control, we must not forget that the best way of controlling men is by persuading them to control themselves.

SOME RECENT IMPROVEMENTS IN FOREST FIRE ORGANIZATION AND FIGHTING

BY C. A. CONNELL

(*Forestry Commission*)

INTRODUCTION.

THERE can be few foresters who have not at one time or another in their career had to fight forest fires with nothing more than man-power equipped with birch-brooms, courage, and a fierce determination, and at the cost of great physical agony. All such have thought or forcibly expressed the view that it ought not to be beyond human ingenuity for man to be equipped more satisfactorily for this fight against a strong enemy. The present mechanical age has at last provided an answer to the problems. The technique of fire-fighting in forests has already been revolutionized, but much greater development lies ahead, and only awaits the passing of the present national emergency. A word of caution is, however, necessary. All who have fought forest fires by the new methods are agreed that these methods are complementary to the old, orthodox, purely manual ones, and while they undoubtedly will outshine the latter, will never entirely replace them, such is the variety of terrain, crop, and other local conditions encountered by the forest fire-fighter.

THE PROBLEMS OF FIRE-FIGHTING.

The efficiency with which a plantation fire can be tackled is dependent on the speed with which the alarm is raised, ease of access to all parts of the forest not only for men but for equipment, the speed with which adequate man-power and appliances can be warned and assembled, and the degree to which control can be exercised over the actual fire-fighting operations. It is axiomatic that an attack on a fire in its early stages is the ideal. A small number of men and appliances right at the start is worth more than a regiment of troops an hour later, and any Fire Plan should give this factor high priority. It is not, of course, suggested that provision should not be made for bulk reinforcements following up the initial assault party, but it is the latter that needs the careful and precise planning.

There are many forests in country characterized by mountains and low population per acre. Movement about the area is thus limited by gradients, watercourses, peat and bog sites, and so on. The collection of an adequate labour force from a country-side holding only scattered cottages or farmsteads and many miles from an urban centre presents considerable difficulties, even if the problems of warning speedily all these people have been solved.

Years ago it was the practice when afforesting large tracts of land to have sufficient rides for administrative purposes only, and this resulted in compartments of up to 60 acres in extent. Doubtless the underlying idea was to have the maximum area under forest production, but the practice jeopardizes an efficient fire-control system from the start.

Fires have occurred and unfortunately are likely to occur in the future involving large tracts of forest, one thousand acres or more in extent and many miles in depth. Such an outbreak complicates enormously the efforts of a fire controller to co-ordinate his counter-measures and switch the forces at his disposal from one location to another rapidly, and even to get his orders transmitted and acted upon before they are outdated by the march of events.

The very state of a plantation has often in the past presented a barrier to the prevention of its destruction. Problems of expense and man-power have in some cases prevented the brashing of pole plantations or the removal of decayed and blown trees. These circumstances and similar ones make entry into the wood to get at the fire hazardous to life and limb.

MODERN DEVELOPMENTS.

Access

It is the practice nowadays to pay considerable attention to ease of movement for men and machines about the forests. The manner in which access is provided in mountainous afforested areas, non-mountainous afforested areas, and re-afforested areas of both types is the same in broad conception but varies in detail.

Where access routes are being planned and laid out before planting mountainous afforested areas, an arterial system of main rides is laid down. These are based on a physical reconnaissance of the terrain, and make use of the most favourable natural features such as firm ground, gradual gradient, and absence of short-radius curves. Bridges and culverts are often necessary, and cognizance has to be taken of the possibility of landslides on to the road. The actual construction depends largely on skilful use of those modern juggernauts, the bulldozer and grader. The rest of the forest is compartmented out so as to give rides running along the contours and sub-compartmented by contourwise and cross-contour tracks, breaking the plantable area down into blocks of as near to 5 acres as is practicable.

Where there is an established forest and a modern system of access is to be developed, the same layout applies, tempered of course by the desirability of incorporating existing rides. Felling out of strips is generally necessary and may entail bulldozing out of conifer stumps, but this is not often essential. The stumps can be straddled by vehicle tracks and men can run in between them.

In flat and rolling country such as East Anglia, the east Midlands, the New Forest area, the Black Isle, and so on, the problem is enormously simplified. Before planting or after a crop has been established it is an easy matter to lay out a complete access system on a rectangular basis or something approaching thereto, bringing blocks of trees down to 5 acres in extent. The bulldozer can cut firm routes for vehicles straight out on sand areas with low rainfall and Calluna vegetation at $\frac{1}{2}d.$ per yard super. On peat areas where drainage is essential, a grader can form a cambered ride with drainage each side for rather more cost.

Cut-over hardwood, conifer, and mixed woodlands are more expensive to condition for fire-access purposes, since large stumps frequently abound and a complicated system of drainage will brook no interference. Large stumps up to 5 feet across have been very successfuly ejected from rides by a dose of 5–8 lb. of

Polar Ammon Gelignite, the total cost being under 10 shillings per stump. The craters and the smaller stumps are dealt with by bulldozing. Watercourses are nowadays dealt with cheaply and permanently by the use of the appropriate size of unglazed or concrete pipes offered in wide variety by brickworks. Simply laid by hand and earth-graded over by machine, the resultant job is permanent and effective.

Width of rides

When planning the layout of a forest it is important to consider not only the number and location of rides and sub-rides but also their width. Rides are not connected only with fire-control schemes; they serve as places on which conversion of poles from thinnings can be carried out, and at the end of a rotation they serve as traffic lanes for the timber drags extracting sawmill-size trees. In addition, rides are administrative boundaries and no forest can be worked in an orderly manner without them. A sense of proportion is necessary, however. The forester cannot overlook the fact that rides are normally unproductive, or that if rides were intended to be automatic fire-stops any forest would be, so to speak, all rides and no trees. Only when a forest crop is in its infancy, that is up to 5 feet in height, can a main forest ride be used as a fire barrier. After this time in a forest crop's life a fire is carried across all normal rides by sparks and the ride serves as a fire-fighting base-line only.

Thus there are restraining factors on any idea of over-generous planning of communication routes, and a severely practical outlook is necessary. Certain latitude is permissible from area to area, since local factors should never be ignored, and no absolute figure of width of rides in feet can be propounded, but it is normal practice nowadays to have a forest divided up into 25-acre compartments by rides 30 to 40 feet wide with perhaps one main arterial route of 60-feet width on a very large forest area. The internal or sub-rides forming sub-compartments of plantations need not be wider than 15 feet, and in the case of an established crop at the pole stage the removal of two rows of trees always meets the case. Such an arrangement of rides and sub-rides accounts for approximately 10 per cent. of the total area under management, and the loss of productivity entailed may be considered a reasonable premium for what is undoubtedly an adequate insurance against serious ravage. A point of importance in the assessment of acceptable fire risk and one not often appreciated is the uncertainty that one can ever replace exactly the damaged property. A burnt-down house can be replaced by an absolute replica simply by taking the architect's plans from the Bank strong-room, but no one can say that in 20 years' time after a fire that has burnt down a 20-year tree crop one will have a new crop similar to the one lost. This element of considerable uncertainty is worth an extra premium to cover additional safeguards.

In the matter of detail, where sub-rides debouch into main rides the corner trees often have to be removed to allow a gentle turn. The stumps of coniferous trees up to 25 years old form no impediment if the trees have been felled in a workmanlike manner, that is with stumps flush with the ground. Many woodland

areas in the districts enumerated have a solidity of soil and a type of vegetation which does not call for any bulldozing at all, simply the cutting of the ride or sub-ride.

Brashing of plantations

Allied to the above-detailed system of forest access is the present technique of brashing plantations so as to permit rapid passage between the rows of trees. Whether partial or complete brashing is done, the slash is generally packed into the alley-ways between the rows so as to leave every third or fourth alley-way entirely free from slash. This is of enormous advantage when fire-fighting at night. Nothing is more conducive to timidity than the fear of stumbling over branches and sustaining physical injury. The light of an ordinary torch is quite inadequate when the fire-fighter is looking into sheets of flame. The knowledge that the fire front can be reached down a cleared path maintains morale. The failure to brash established plantations was commented on earlier. Quite apart from the silvicultural desirability of this operation, brashing is a worthwhile premium against extensive fire losses. No one can satisfactorily fight a fire when hampered by dead and tough branches reaching to ground level. Eyes get damaged, clothes ripped, and speedy movement along the fire face or flank is prevented. Again, brashing has prevented many a ground fire from developing into a crown fire. The possible losses from a crown fire need no elaborating.

The use of water

The foregoing defence measures apply to all methods of forest fire-fighting. There has been developed in the State-owned forests of the United Kingdom, in addition, a specialized technique for fire-fighting involving the use of water. It was said for many generations that a forest fire could only be overcome by blood and sweat and that nothing in the way of water beyond the Wajax pack was applicable to the problem. This has been conclusively disproved in recent years. The technique has been developed on the basis of relatively small quantities of water transported to the scene of the fire and delivered by light-weight pumps of low consumption and high-pressure output. It is a fact that a small volume of water thrown at high pressure will extinguish a crown fire in plantations up to 25 years of age, and will hold a fire in older woods until water on a more copious scale can be brought up. The fire is knocked out as well as watered out, and some idea of the force used can be gained from the experience of stripping the overbark down to the bast on a 20-year-old pine tree by playing a single jet on it.

There are on the market a number of pumps made of modern light-weight alloys by firms such as Merryweather, Johnson (Homelite), Scammel, and Evinrude, among others. These pumps, chiefly of the centrifugal type, consume water at the rate of 8 to 25 gallons per minute and eject it through one or two $\frac{1}{4}$-inch or $\frac{7}{32}$-inch nozzles at pressures about 65 lb. per square inch. This results in a jet 60 feet long, capable of being thrown with force against the crowns of the average young and middle-aged coniferous crop. These pumps are powered by petrol engines ranging in size from $2\frac{1}{2}$ to $4\frac{1}{2}$ h.p. built as one unit with the pump and of

modest petrol consumption. The usual equipment per pump consists of 400 feet of rubber or rubber-lined hose, one dividing breech, and two branch pipes with $\frac{1}{4}$-inch or $\frac{7}{32}$-inch nozzles. With 400 feet of hose every part of a 5-acre block of trees can be reached by the jet of water. The pump with etceteras is transported together with a 500-gallon circular or rectangular metal tank of water on a lorry to the scene of the fire. Various types of lorries have been the subject of experiment, and of those available at the present time the type having twin-driven rear axles and Trakgrip tyres is the best for all terrains.

The use of water in small volumes at high pressure does not stop at power-driven and lorry-borne equipment. Considerable tactical development has been made in the use of an appliance which is an improvement on the canvas water pack of years ago. This is the Bantam hand-pump, consisting of a container of 3 gallons capacity with a hand-pump integral with the container. The pump gives a jet identical with the now all too familiar stirrup pump. The whole outfit, filled with water, can be handled by one man without undue fatigue and can even be carried full for reasonable distances up mountain sides.

A 10-cwt. van carrying one 50-gallon cube-shaped metal container of water, four Bantam pumps, and three men plus the driver forms an ideal emergency fire-fighting outfit which can be rushed to a fire immediately on receipt of the warning. There is a good sporting chance of such a team holding a fire in a young plantation until the proper fire-fighting forces arrive, while an outbreak in a newly planted area of bracken, grass, or Calluna vegetation can be quickly extinguished. Such an outfit is ideal for a small forest unit, where economic aspects preclude the purchase and maintenance of more elaborate equipment. A large coniferous forest generally has a power-driven pump on a lorry, as described earlier, as its spearhead of attack. Many fires which would certainly have developed into major conflagrations involving hundreds of acres of woodland have been either extinguished or held in check by the prompt use of such a vehicle. These outfits, known as Mobile Dam Units, have a crew of four including lorry driver and are held at instant readiness at Fire Control Centres.

Water-supplies

It is obviously of restricted utility having water fire-fighting equipment dependent on the Fire Control Centre for water. This aspect of the case has been met in waterless areas by siting large-capacity metal tanks on gantries in the forest at points of known or potential high fire risk. These tanks, which hold from 500 to 5,000 gallons of water, give a very rapid gravity feed into the water-tank on the Mobile Dam Unit, 500 gallons being passed in under 5 minutes through a 2-inch fullway cock.

In the mountainous and other areas where natural watercourses abound, it is the practice to dam up a stream or dike and thereby form a reservoir from which a Mobile Dam Unit can replenish its tank. Nor is the use of such natural supplies confined to areas equipped with power machinery. Full advantage can be taken of every spring or rivulet or small artificial dam by placing beside it in a suitably contrived box one or more Bantam pumps. A small earth and stone embankment

retaining 100 gallons of water, together with two Bantam pumps, forms a water fire-fighting unit ideal for isolated and mountainous parts. The fire-patrol men and scattered tenant workers, knowing the location of all such water appliances, can perform valuable service where otherwise the use of fire-beaters only would prove ineffectual.

There are types of fire hazard where the placing of Bantam pumps with related water-supply, either natural or artificial, is the most sensible way of combating the risk. One such is the stretch of railway line known to have a bad record of fire-raising in young plantations. The placing of a 40-gallon steel drum of water and one Bantam pump every four chains down the section of line will enable one fire-fighter patrolling the length to cope with all but the worst the train can do, and the presence of so many water outfits will enable further fighters to cope with the worst.

Warning and Control

The developments in warning and fire control have not been spectacular as have other aspects of forest fire-fighting. This is not because technique has lagged behind, but because the war has prevented the necessary equipment being available. The observation tower and the telephone still remain the king-pins of most warning systems, while the uncomfortable motor-cycle is often the servant of the Fire Controller who wants to rush round the perimeter of a large fire.

TREND OF FUTURE DEVELOPMENT.

It is likely that the greatest progress will be made in the spheres of transport, warning, and fire control.

Front-wheel drive vehicles with good clearance but low centres of gravity, and with power take-off for direct driving of pumps by the road engine, will undoubtedly be available. These will be able to traverse terrains which now tax the conventional lorries. Tracked vehicles on the lines of the famous Bren gun carrier will revolutionize methods in mountainous country. One can imagine the current Mobile Dam Unit being replaced by a team of three such carriers, one loaded with the water-tank, one with the pump, hose, and other equipment, and one carrying personnel. Their speed and manœuvrability will facilitate a lightning attack on the most difficult sites.

In the matter of giving warning of outbreaks of fire, science may provide methods which our forebears would have put down to Black Magic. The role of the photo-electric cell and the thermal unit is likely to be expanded beyond belief, and it is possible that one day forest areas will be guarded by all-seeing but unseen eyes, operating automatic alarms in the Fire Control Centres within minutes of smoke ascending and the temperature rising. Short-wave radio will assuredly be the medium of fire-fighting control within a short time after the present war is over. The advent of the 'walkie-talkie' and the more powerful car-borne transmitter will make possible an admirable system of co-ordination and control of personnel and equipment. One envisages the Fire Controller at the edge of the fire, seated in his car, headphones and larynx-microphone in place, studying his

map of the forest. Each ganger in charge of a squad has his 'walkie-talkie' and each mobile water unit its counterpart. The Controller gets minute-to-minute reports from fighting personnel and from observers posted round the fire area, and disposes his forces according to the changing conditions via radioed orders. On really large forests the Controller on the ground will one day be replaced by the Controller in his helicopter. Visual assessment of the course of the fire will replace verbal radioed accounts. The Controller will radio his orders to his ground forces and will realize the dream of every keen fire-fighting officer, to be able to see the whole fire in plan from above instead of part of it upwards from below.

As to the actual fire-fighter, the P.B.I. of the whole organization, he may well be helped by the use of foam. At the present time putting out a forest fire by foam is often impracticable and always costly, but such fires have been successfully so dealt with, and the technique may well be developed and cheapened in the years to come. Asbestos protective clothing has also been used in isolated instances, and here again developments may be anticipated. Science will tame Nature.

SUMMARY.

The subject of access to forest areas for fire-fighting purposes is being developed on lines of major and minor ride systems breaking down woodlands to blocks of 5 acres or thereabouts. The rides in difficult terrain are formed by bulldozers and graders.

The use of water has been very successfully added to the conventional beating technique for combating forest fires. The water may be manually or power-pumped. Economic use of limited water-supplies is ensured by low-consumption high-pressure light-weight pumps.

Specialized vehicles derived from war developments, radio, and other scientific devices will materially aid the forest fire-fighter in the future.

The facilities for experiment, research, and development on the subject have been provided by H.M. Forestry Commission, to whom the writer is indebted.

ON THE DETERMINATION OF QUALITY CLASS BY 'TOP' HEIGHT INSTEAD OF MEAN HEIGHT FOR CONIFERS IN GREAT BRITAIN

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THE Forestry Commission Yield Tables (4) are divided into Quality Classes on the basis of Mean Crop Height for age. Mean crop height is here defined as the average height of the trees of Mean Basal Area.

Mean crop height is usually determined by selecting samples covering the range of diameter or girth classes encountered in the crop, measuring their heights, plotting these heights against diameter or girth, drawing the best fitting curve of the relationship of height to diameter, and reading from this the average height of the tree of mean basal area. It can also be determined by Lorey's formula as the weighted average of heights sampled in size classes, the weighting being by the basal areas of the size classes. The arithmetic mean of a number of sampled trees of, or close to, the mean basal area is also acceptable as estimate of mean crop height.

Thus defined, mean height is a crop statistic of considerable value. It is an average derived from the full range of diameter and takes into account the variation in height which is correlated with diameter. The variation in height uncorrelated with diameter should be covered in sampling. Present practice is to use selective sampling, choosing the trees judged to be of average height for their diameter; this allows the entry of errors of judgement, but with experienced operators the magnitude of the possible error is small. If circumstances necessitated it, selective sampling could be replaced by the random sampling of a series within each size class, enabling the extent and probability of the sampling error to be determined.

This mean height is also that required for the determination of the volume of the standing crop by the equation: *Volume of crop* = *Total basal area* × *Mean height* × *Crop form factor*, and as such must always be determined if volume statistics of the crop are to be found by that method.

As an index of the quality of the site, however, mean height thus defined and determined is open to objection on two grounds. Firstly, as an average to which all size classes contribute, it is liable to be affected by the management to which the crop has been subjected, as well as by the factors of its site, and it is these latter factors alone which it is desired to assess in establishing the quality of the site. Secondly, its determination is an unnecessarily cumbrous and slow proceeding when assessment of the quality of the site is the sole objective.

These objections have led to the replacement of mean top height by other height measurements as indices of quality in America and India. In America the average height of the dominant trees of the crop has been generally accepted (1)

as the best height index for quality of site on the grounds that it is not liable to be affected by management *but solely by the site factors*. A considerable range of height still occurs within the dominant trees of the crop, so that the height used must still be an average, and the extent of the population to which this statistic applies must be determined before it can be determined by sampling. The measurement of the diameter or girth of all the trees in a sample as a prior necessity for the determination of mean crop height must at least be replaced by the classification of all trees in a sample as to dominance prior to the determination of average dominant height if this is taken as the arithmetic mean of a sample of dominants; while if dominant height is taken as the average height of the trees of mean basal area within the dominant class, the classification of the stems as to dominance is additional to the measurement of the diameter or girth of the dominant class at least. Thus the use of Dominant Height as an index of quality of site, though free from the first objection raised against mean crop height, is equally, or possibly more, open to objection on the second ground as being cumbrous and slow.

In India the height now used as the index of quality is termed Top Height and is defined as the arithmetic mean height of the hundred trees of largest diameter per acre in the crop, excluding forked trees or trees with defective crowns (2). It is, therefore, an average of dominant trees and as such is unaffected by management, but as the portion of the crop to be sampled is strictly defined as the 100 trees of largest diameter per acre, sampling is simple and quick. A full hundred trees need not be sampled unless a sample plot of a full acre is being used; it is quite satisfactory to take the mean height of the ten largest-diameter trees on a 0·1-acre sample plot and even the mean of five on a 0·05-acre plot can be used. Callipering or girthing of all the trees on the plot is unnecessary, as on a small plot the largest trees can be picked out by eye and unless defective in the crown are acceptable as samples for height.

During the course of the 'University Forestry Research Project' on the growth of timber crops and site factors carried out by parties from various Universities in conjunction with the Imperial Forestry Institute on behalf of the Forestry Commission, it was decided to change over to work on a top height basis to simplify procedure and to meet the objections of several ecologists in the parties who felt that mean crop height as determined did not reflect the resultant of the site factors. The first season's work, in the summer of 1940, had been carried out entirely on a basis of mean crop height, a simplified form of the Forestry Commission's sample plot procedure being undertaken in each plot. During the second season's work in the summer of 1941 top height and not mean height was determined for plots of all the common conifers for which adequate yield tables already existed and of ages covered by these tables. The correlation, or correlations, between top height and mean height for each of these conifers, Scots and Corsican pine, European and Japanese larch, Norway and Sitka spruce, and Douglas fir had, however, to be determined before the quality of the 1941 plots could be assessed by reference to the existing tables. Data for the determination of these correlations were, however, available in the records of the 1940 University

Forestry Research plots and the files of the Permanent Sample Plots of the Forestry Commission.

Top height as such had not been determined for either set of data, but from the records of the University Forestry Research plots the range of size of the largest trees on the plots in the proportion of 100 per acre could be determined, and the heights of trees sampled within this range used to make an estimate of top height as their mean, or read off as the graphed average height against the mean top girth (arithmetic mean of the 10 largest trees in the 0·1-acre sample plot). Both figures were determined and in most cases coincided, but where they differed the height determined graphically was generally accepted as the better estimate.

As these were only estimates of top height for each plot, not exact determinations, it would not have been permissible to base correlations on these alone. Fortunately the standard procedure for collection of data in the Permanent Sample Plots of the Forestry Commission includes the measurement of height of a large number, 10 to 20, of the dominant trees, and the determination of the average height of the mean tree of the largest group under Block's system of grouping. This as used in sample plot procedure in Britain (5) is not identical with top height for all sizes of plots, but where it varies the difference is insignificant. It was possible, therefore, to check the estimates of top height from the University Forestry Research 1940 data by Permanent Sample Plot data, and it was found, as can be seen from Diagrams 1, 2, and 3, that there was no significant difference between them.

The data derived from both sources were used, therefore, in the determination of the correlation between mean and top height for each species. This correlation was found to be rectilineal in form for all species with a very high Correlation Coefficient +0·994 for European larch, +0·989 for Scots pine, and +0·974 for Norway spruce, the last on only 28 paired observations. Japanese larch was found to fit the regression line of European larch, and Corsican pine that of Scots pine. The number of observations on Sitka spruce was insufficient to prepare a separate regression line, but those available fell in line with the Norway spruce, and it is considered safe to use the correlation for Norway spruce for Sitka spruce also. The correlation for mean top height for Douglas fir was also determined. There was greater variation in the individual values than in the other species, but a single correlation was quite satisfactory. (The exact figures are not available to the writer at present.)

From the regression lines of top height for mean height, and the curves and tables of mean height for age of the various quality classes in the Forestry Commission Yield Table, curves and tables showing top height for the same ages were prepared for the assessment of all plots of the University Forestry Research parties in which top height was sampled. The tables appended to this article give the top heights along with the mean heights for all ages and qualities as given in the Forestry Commission Yield Tables and can be used for assessing the quality of any crops whose age and top height are known.

Before discussing the practical application of these tables, however, two points

should be considered. It is generally stated that mean crop height, being affected by management, does not provide a reliable index of site quality. If this is true, any correlation between top height and mean crop height should vary with treatment, and the general relationship could only be the average of a wide dispersal. This is certainly not the case in the data available for these correlations, though the University Forestry Research plots covered all types of woods from neglected and unthinned, through well tended, to overthinned and open crops—with a probable bias towards underthinned crops. The Permanent Sample plots have each been subjected to one recorded type of thinning. The Low Thinning and Crown Thinning plots were specially studied to see if the thinning régime did alter the relationship, but no significant difference was found. The second point is the very high correlation found between the two measures of height. If in their determination one is likely to affect the other, they must show a high correlation irrespective of the types of crop in which they are determined. This is undoubtedly the case when mean crop height is determined graphically, as is the case in all permanent sample plot work and in the preparation of the Yield Tables. The curves drawn will always be greatly affected by the heights of the trees sampled in the larger size classes, and these are in fact a good estimate of top height. The high correlation between mean crop height and top height is therefore to be expected and signifies nothing except that, as defined, it is possible to make a good average estimate of the one from the other.

This does not, however, affect the first point; it would still be possible for a series of relationships depending on the thinning régime to occur each with a high correlation coefficient for this reason. Why only one relationship should be found for each of these conifers, identical for the two species of pine and the two species of larch, and very similar for all, requires more consideration. One important reason lies in the definition of mean height as the average height of the trees of mean basal area, not, as non-foresters might imagine, the arithmetic mean of all trees in the crop. This in essence is a method of heavily weighting the importance of the larger trees in the crop, so that in a crown-thinned plot, though a considerable number of small suppressed trees may occur and would undoubtedly reduce the arithmetic mean height of the crop, the mean basal area and hence the mean crop height may be only slightly affected. The other important reason the writer would suggest is the distribution of heights of the stems in a close-grown even-aged crop. This differs among species, being closely related to their tolerance of shade. The variation of height between and within size classes is usually fairly wide, but with light-demanding or only moderately shade-bearing species, to which classes all the conifers dealt with here belong, it is definitely limited. If the heights of all trees on a sample plot are measured and plotted against their diameter, the scatter diagram thus formed shows a definite positive correlation of height and D.B.H. but an even and fairly wide dispersion within size classes (as the writer found using the data for the clear-felled Scots pine plot in Germany used by Chaturvedi in his *Measurement of the Cubical Contents of Forest Crops* (3)). From experience of the plots of the University Forestry Research and inspection of numerous girth/height graphs of permanent sample plots, the writer would

estimate the range of heights within a size class at about 10 feet, and the difference between the mean of the largest and the mean of the smallest also at about 10 feet for larch, with slightly greater ranges in both cases for spruce. These ranges also give the approximate limits above which the individual stem must maintain itself if it is to escape complete suppression and extinction, about 10 feet below the average dominant height for larch and slightly more for Scots pine and spruce. Douglas fir shows considerably greater variation in height within the crop than the other species, but this is due, in the writer's opinion, not so much to greater shade tolerance as to the much greater rate of height growth of the dominants, bringing about a considerable disparity in height between them and the suppressed trees before death or thinning removes the latter and evens up the canopy. The existence of these limits to the variation of height within the crop, and the method of deriving mean crop height reduce considerably the possible variation between mean and top height, so that differences due to different methods of management are probably too small to be detected with the methods of sampling and measurement generally employed, and only one correlation irrespective of methods of management is detectable. This argument is of course only applicable to these light-demanding or moderately shade-bearing conifers under plantation conditions as treated here. No data were available to determine whether significant differences occurred with strong shade-bearers such as *Tsuga* or Silver fir.

The objection to the use of mean crop height as a site quality index for plantation crops of the common conifers in Great Britain as liable to variation with management is, therefore, not substantiated, and the use of top height in its stead in dealing with pure crops can only be pressed on the grounds of its being more easily and rapidly determined in the field. Here the writer considers it has a definite advantage. The location of a plot or plots having been selected or determined (depending on the use of selective or systematic sampling), it is only necessary to determine the limits roughly by pacing and inspect the crop to get some idea of the range of size. The trees to be sampled for height can then be selected, starting from the largest and working downwards, excluding any with defective crowns, until the number appropriate to the size of plot (10 for 0·1 acre, 5 for 0·05 acre) is attained. The arithmetic mean of their measured heights is then the top height of the crop, and the age being known or determined, the quality class can then be assessed using the tables appended to this article. Thus all callipering or girthing of the trees on the plot and the determination of mean basal area is unnecessary, the selection of samples is practically mechanical, and there is no necessity to prepare a graph.

In dealing with mixed crops the use of top height instead of mean height is of considerable advantage. The Yield Tables were prepared from, and apply to, pure crops. In trying to assess the quality of a site bearing a mixed crop it is generally acceptable to work with the mean crop height of the primary species, as it is unlikely to differ greatly from the mean height which would have been attained if grown pure and the site can therefore be assessed in respect of that species. In many cases, however, it would be of great value to be able to assess the quality of the site in respect of secondary species, but here there are considerable

difficulties in using mean height. There is no certainty that the mean basal area of the stems of the secondary species present approaches the mean basal area of a pure crop of the same age, nor that the mean height would be similar. A fairly common instance in the south of England is of crops of larch or pine or both with an admixture of spruce. In the young middle-aged crop the great bulk of the spruce has generally been surpassed in height by the others owing to their greater rate of height growth in early youth and occurs mainly as suppressed stems just surviving with occasional dominant or co-dominant stems. The mean basal area and mean height then do not give a proper indication of the quality of a pure spruce crop grown on that site. If sufficient of the dominant or co-dominant stems can be found, however, the top height of the spruce can be determined and a much better assessment of the site quality in respect of spruce made.

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CONCLUSIONS

From this study, it appears that for the species dealt with, Scots and Corsican pine, European and Japanese larch, Norway and Sitka spruce, and Douglas fir, mean crop height is an acceptable index of quality of site. Top height, however, has the advantage of greater simplicity in its determination and in use in mixed crops. Top height and mean height are simply and closely correlated and these correlations have been determined.

Tables showing top height values for the ages and quality classes of the Forestry Commission Yield Tables have been prepared enabling assessment of quality class by top height to be made.

SUMMARY

1. Mean height or mean crop height as used as the Quality Class index in the Forestry Commission Yield Tables is discussed.

2. Dominant height as used in America and top height as used in India as alternative quality indices are defined and discussed.

3. The investigation of the correlation between top height and mean height in even-aged plantation crops is described and the resulting regression lines and statistics for European larch, Scots pine, and Norway spruce are given.

4. Comparative curves for mean height and top height of European larch and Tables of top height for age for the Quality Classes of the Commission's Yield Tables for all species are given.

5. Significant points regarding these correlations are discussed.

6. The use of top height for site-quality assessment is described and its advantage in assessment in mixed crops is indicated.

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Mean Crop Height and Top Height by Age and Quality

(Based on Forestry Commission's Yield Tables of Bulletin 10)

Scots Pine

Quality Class I Mean height 60 ft. at 50 years			*Quality Class II* Mean height 50 ft. at 50 years			*Quality Class III* Mean height 40 ft. at 50 years		
Age years	*Mean crop height (ft.)*	*Top height of crop (ft.)*	*Age years*	*Mean crop height (ft.)*	*Top height of crop (ft.)*	*Age years*	*Mean crop height (ft.)*	*Top height of crop (ft.)*
25	33	38	..	..	..	..	..	..
30	40	45	30	31	36·5	..	..	..
35	46	50	35	36·5	41·5	35	28·5	34
40	51	55	40	41·5	46	40	32·5	38
45	56	59·5	45	46	50	45	36·5	41·5
50	60	63	50	50	54	50	40	44·5
55	64	66·5	55	54	57·5	55	43	47·5
60	67	69·5	60	57	60	60	46	50
65	70	72	65	60	63	65	49	53
70	72·5	74·5	70	62·5	65·5	70	51	55
75	75	76·5	75	65	67·5	75	53	56·5
80	77	78·5	80	67	69·5	80	55	58·5
85	79	80·5	85	69	71	85	57	60·5
90	81	82	90	71	73	90	59	62
95	83	84	95	73	75	95	61	64
100	84·5	85·5	100	74	75·5	100	62	64·5

EUROPEAN LARCH

Quality Class I Mean height 80 ft. at 50 years			*Quality Class II* Mean height 70 ft. at 50 years			*Quality Class III* Mean height 60 ft. at 50 years		
Age years	*Mean crop height (ft.)*	*Top height of crop (ft.)*	*Age years*	*Mean crop height (ft.)*	*Top height of crop (ft.)*	*Age years*	*Mean crop height (ft.)*	*Top height of crop (ft.)*
20	40	43·5	20	31·5	35·5	..	..	..
25	50	53·5	25	40	44	25	33	37
30	58	61·5	30	48	51·5	30	39·5	43·5
35	65	68	35	55	58·5	35	45·5	49
40	71	74	40	61	64	40	51	54·5
45	76	78·5	45	66	69	45	56	59·5
50	80	82·5	50	70	73	50	60	63·5
55	84	86·5	55	74	76·5	55	64	67·5
60	87·5	89·5	60	77·5	80	60	67·5	71
65	91	93	65	81	83·5	65	71	74
70	94	96	70	84·5	86·5	70	74	77
75	97	99	75	87	89	75	77	79·5
80	100	102	80	90	92	80	79·5	82

Quality Class IV Mean height 50 ft. at 50 years			*Quality Class V* Mean height 40 ft. at 50 years		
30	31·5	35·5	..	..	..
35	37	41	..	..	..
40	41·5	45·5	40	32	36
45	46	49·5	45	36	40
50	50	53·5	50	40	44
55	54	57·5	55	44	47·5
60	57·5	61	60	47·5	51
65	61	64	65	50·5	54
70	64	67	70	53·5	56·5
75	66·5	69·5	75	56·5	59·5
80	69·5	72	80	59	62

Norway Spruce

Quality Class I Mean height 80 ft. at 50 years			*Quality Class II* Mean height 70 ft. at 50 years			*Quality Class III* Mean height 60 ft. at 50 years		
Age years	*Mean crop height (ft.)*	*Top height of crop (ft.)*	*Age years*	*Mean crop height (ft.)*	*Top height of crop (ft.)*	*Age years*	*Mean crop height (ft.)*	*Top height of crop (ft.)*
25	41	45	25	35·5	40	..	..	..
30	51	54·5	30	43·5	47·5	30	36·5	40·5
35	59	62·5	35	51	54·5	35	43	47
40	66·5	69·5	40	58	61·5	40	49	52·5
45	73·5	76	45	64·5	67·5	45	55	58·5
50	80	82·5	50	70	73	50	60	53
55	86	88	55	75	77·5	55	64	67
60	91	93	60	79	81·5	60	68	71
65	96	97·5	65	83	85·5	65	72	74·5
70	100	101·5	70	87	89	70	75	77·5
Quality Class IV Mean height 50 ft. at 50 years			*Quality Class V* Mean height 40 ft. at 50 years					
35	34·5	39	..	..	..			
40	40	44	40	31	35·5			
45	45	49	45	36	40·5			
50	50	53·5	50	40	44			
55	54·5	58	55	44	48			
60	58	61·5	60	47·5	51·5			
65	61·5	64·5	65	50·5	54			
70	64·5	67·5	70	53	56·5			

Douglas Fir

Quality Class I Mean height 110 ft. at 50 years			*Quality Class II* Mean height 100 ft. at 50 years			*Quality Class III* Mean height 90 ft. at 50 years		
Age years	*Mean crop height (ft.)*	*Top height of crop (ft.)*	*Age years*	*Mean crop height (ft.)*	*Top height of crop (ft.)*	*Age years*	*Mean crop height (ft.)*	*Top height of crop (ft.)*
15	38	46·5	15	33	42	..	..	..
20	53·5	60	20	46·5	54	20	39·5	48
25	67	72·5	25	58·5	64·5	25	51	58
30	78	82·5	30	69	74	30	60·5	66·5
35	87	90·5	35	78	82·5	35	69	74
40	95·5	98	40	86	89·5	40	76·5	81
45	103	105	45	93·5	96	45	83·5	87
50	110	111	50	100	102	50	90	93
Quality Class IV Mean height 80 ft. at 50 years								
20	33·5	42·5						
25	43	51						
30	52	59						
35	60	66						
40	67·5	72·5						
45	74	78·5						
50	80	84						

CORSICAN PINE

Quality Class I Mean height 70 ft. at 50 years			*Quality Class II* Mean height 60 ft. at 50 years			*Quality Class III* Mean height 50 ft. at 50 years		
Age years	*Mean crop height (ft.)*	*Top height of crop (ft.)*	*Age years*	*Mean crop height (ft.)*	*Top height of crop (ft.)*	*Age years*	*Mean crop height (ft.)*	*Top height of crop (ft.)*
20	29	34·5	20	23·5	30	20	18·5	25
25	37·5	42·5	25	31	36·5	25	25	31
30	45	49·5	30	38	43	30	31	36·5
35	52	55·5	35	44	48·5	35	36	41
40	58·5	61·5	40	49·5	53·5	40	41	45·5
45	64·5	67	45	55	58·5	45	45·5	50
50	70	72	50	60	63	50	50	54

JAPANESE LARCH

(Macdonald's Provisional Yield Table 1935)

Quality Class I Mean height 50 ft. at 25 years			*Quality Class II* Mean height 40 ft. at 25 years			*Quality Class III* Mean height 30 ft. at 25 years		
Age years	*Mean crop height (ft.)*	*Top height of crop (ft.)*	*Age years*	*Mean crop height (ft.)*	*Top height of crop (ft.)*	*Age years*	*Mean crop height (ft.)*	*Top height of crop (ft.)*
10	23·5	28	10	16	20·5	..	..	..
15	34	38	15	25·5	30	15	17	21·5
20	43	46·5	20	34	38	20	24·5	29
25	50	53·5	25	40	44	25	30	34·5
30	56	59·5	30	44·5	48	30	34·5	38·5
35	60·5	63·5	35	48	51·5	35	38	42
Quality Class IV Mean height 20 ft. at 25 years								
15	9·5	15						
20	15	20						
25	20	24·5						
30	24	28·5						
35	27·5	32						

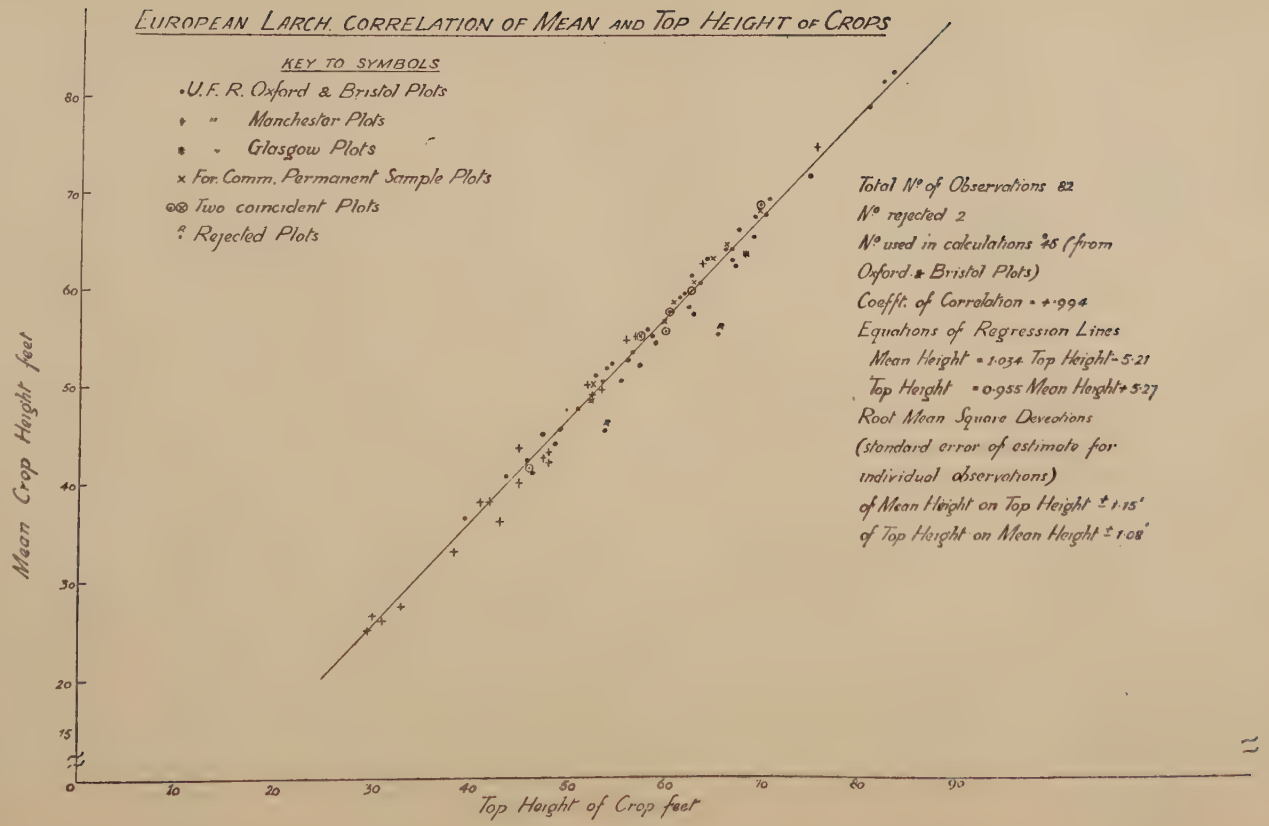

EUROPEAN LARCH. CORRELATION OF MEAN AND TOP HEIGHT OF CROPS
KEY TO SYMBOLS
•U.F.R. Oxford & Bristol Plots
" Manchester Plots
- Glasgow Plots
× For. Comm. Permanent Sample Plots
⊙⊙ Two coincident Plots
? Rejected Plots
Total N° of Observations 82
N° rejected 2
N° used in calculations 78 (from Oxford & Bristol Plots)
Coefft. of Correlation = +·994
Equations of Regression Lines
Mean Height = 1·034 Top Height − 5·21
Top Height = 0·955 Mean Height + 5·27
Root Mean Square Deveations (standard error of estimate for individual observations)
of Mean Height on Top Height ± 1·15'
of Top Height on Mean Height ± 1·08'
Mean Crop Height feet
Top Height of Crop feet
0
10
15
20
30
40
50
60
70
80
90

DIAGRAM 1.

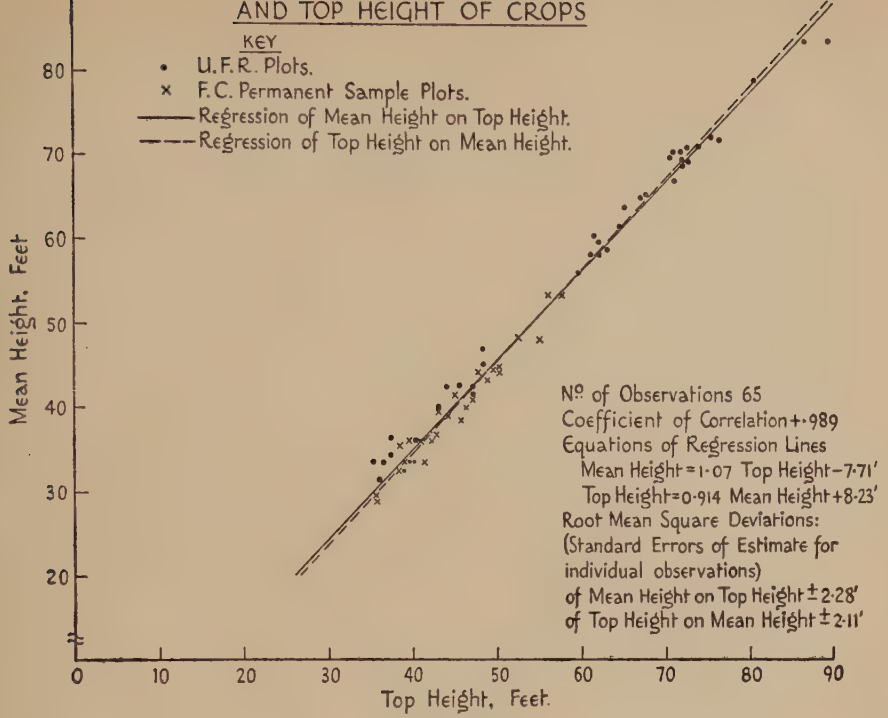

AND TOP HEIGHT OF CROPS
KEY
U.F.R. Plots.
F.C. Permanent Sample Plots.
Regression of Mean Height on Top Height.
Regression of Top Height on Mean Height.
Mean Height, Feet
Top Height, Feet.
No of Observations 65
Coefficient of Correlation +·989
Equations of Regression Lines
Mean Height = 1·07 Top Height − 7·71'
Top Height = 0·914 Mean Height + 8·23'
Root Mean Square Deviations:
(Standard Errors of Estimate for individual observations)
of Mean Height on Top Height ± 2·28'
of Top Height on Mean Height ± 2·11'

DIAGRAM 2.

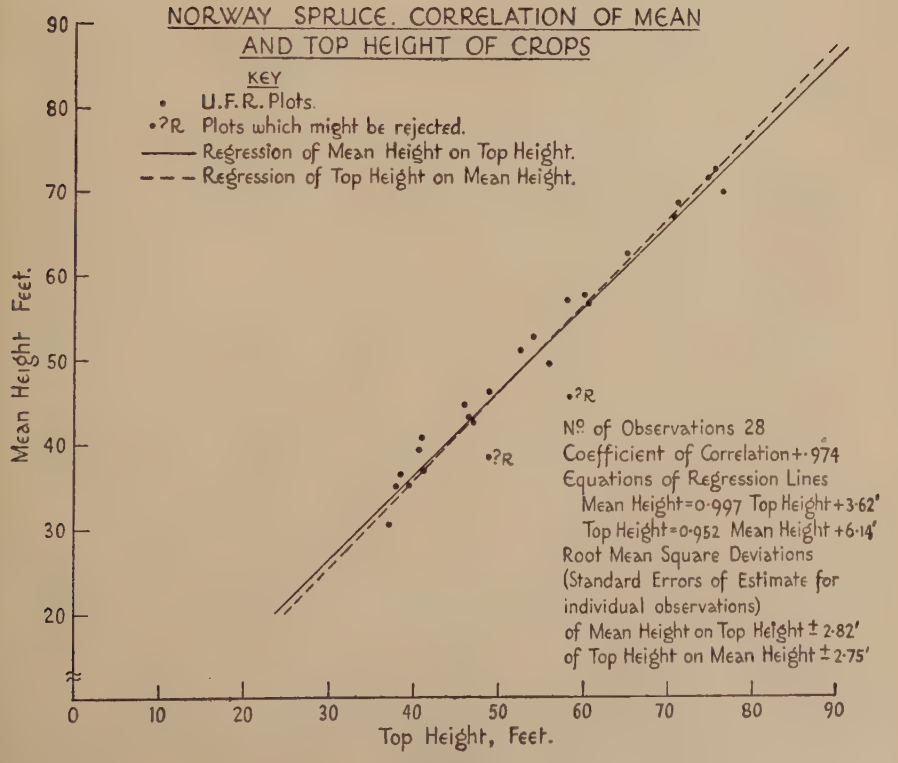

NORWAY SPRUCE. CORRELATION OF MEAN AND TOP HEIGHT OF CROPS
KEY
U.F.R. Plots.
?R Plots which might be rejected.
Regression of Mean Height on Top Height.
Regression of Top Height on Mean Height.
Mean Height Feet.
Top Height, Feet.
No of Observations 28
Coefficient of Correlation +·974
Equations of Regression Lines
Mean Height = 0·997 Top Height + 3·62'
Top Height = 0·952 Mean Height + 6·14'
Root Mean Square Deviations
(Standard Errors of Estimate for individual observations)
of Mean Height on Top Height ± 2·82'
of Top Height on Mean Height ± 2·75'

DIAGRAM 3.

NOTES ON FOREST MENSURATION

Contributed by the IMPERIAL FORESTRY INSTITUTE, OXFORD

I. TAPE VERSUS CALLIPER.

CHATURVEDI (2) compares the cross-sectional areas of trees calculated from measurements made with tape and calliper by reference to an ellipse. If a and b are the semi-major and semi-minor axes of the ellipse, the true area is πab, but in practice the area is calculated from either

(1) $\pi\left(\frac{a^2+b^2}{2}\right)$, the mean of the squares,

or (2) $\pi\left(\frac{a+b}{2}\right)^2$, the square of the mean.

If P is the perimeter of the ellipse, the area is assumed to be $\frac{P}{4\pi}$.

Chaturvedi gives the first four terms of the series which expresses the perimeter of an ellipse in terms of the axes:

$$P = 2a\pi\left(1 - \frac{e^2}{4} - \frac{3e^4}{64} - \frac{5e^6}{256}\right).$$

The next three terms are

$$-\frac{175e^8}{16384} - \frac{441e^{10}}{65536} - \frac{4851e^{12}}{1048576},$$

where e is the eccentricity and $e^2 = \frac{a^2-b^2}{a^2}$.

Calculations from these values of a, b, and P for ellipses with major and minor axes of 20×16 and 20×12 are given below—all need multiplying by π to give areas.

	20×16	20×12
Mean of the squares (1) .	82	68
P using 1 term . .	100	100
„ 2 terms . .	82·81	70·56
„ 3 „ . .	81·708	67·371
„ 4 „ . .	81·543	66·533
„ 5 „ . .	81·511	66·241
„ 6 „ . .	81·5036	66·123
„ 7 „ . .	81·5018	66·0721
Square of the mean (2) .	81	64
True	80	60

The areas calculated from P converge slowly, but Fletcher (4) has since published a table of elliptic integrals; areas calculated from values of P given in these tables for ellipses with axes of 20×16 and 20×12 are

20×16	20×12
$\pi\times81{\cdot}5012$	$\pi\times66{\cdot}0237$

An attempt has been made to confirm these results in practice. A 41-year-old Douglas fir (Vancouver) sample plot was being remeasured, the points for breast-high measurements being permanently marked on the trees. Measurements of girth were made with a steel tape graduated in eighths of an inch, and of two diameters at right angles with a Flury calliper graduated in tenths of an inch; there was no difference between the tape and calliper graduations when checked; girths were recorded to the nearest quarter-inch and diameters to the nearest tenth. The results are given in the appendix, the first diameter being oriented approximately north–south.

Considering eccentricity as the difference between the two diameters of a tree, ignoring signs, the mean difference with its standard error is $0{\cdot}278 \pm 0{\cdot}023$ inches and so eccentricity is present; the basal areas calculated from diameter and girth measurements should accordingly conform with theory. The mean basal areas in square feet are:

Mean of squares (1)	0·33542
Girth	0·34271
Square of mean (2)	0·33526.

The differences between these means and their standard errors are

Girth — mean of squares . .	$0{\cdot}00728 \pm 0{\cdot}00066$
Girth — square of mean . .	$0{\cdot}00745 \pm 0{\cdot}00067$
Mean of squares — square of mean .	$0{\cdot}00016 \pm 0{\cdot}00003$,

all the differences being significant.

Thus the results do not conform to theory, the basal area calculated from girth being greater than either of the values calculated from diameters; the probable explanation is that the tape used was $\frac{3}{8}$ inch wide while the bearing surfaces of the calliper arms were only $\frac{3}{16}$ inch wide, consequently the calliper beds down into cracks and other depressions over which the tape passes; possibly both trees and eccentricity are too small with reference to the rounding-off limits adopted.

Appendix

1st diameter . .	4·0	9·1	7·0	7·2	7·5	5·6	8·7	7·4	9·9
2nd diameter . .	4·1	9·4	6·7	7·4	7·3	5·4	9·2	7·4	9·9
Girth . . .	13¼	28¾	21¾	23¼	23¼	17½	28¼	23½	31½
1st diameter . .	6·8	6·8	9·9	8·4	9·6	6·4	7·2	10·8	7·9
2nd diameter . .	6·8	7·2	9·6	8·2	9·0	7·1	7·3	10·7	7·7
Girth . . .	21½	22¼	31¼	26	29¼	21¾	23	34¼	24¾
1st diameter . .	7·5	10·0	6·5	7·3	4·1	5·1	5·9	4·8	4·5
2nd diameter . .	7·4	9·8	6·1	7·3	3·9	4·9	5·8	5·0	4·5
Girth . . .	23¾	31½	20	23¼	12½	16	18½	15½	14½
1st diameter . .	3·0	9·0	7·7	10·8	9·1	3·3	5·5	7·1	6·5
2nd diameter . .	3·3	9·0	8·1	10·6	8·9	3·4	5·1	6·9	6·5
Girth . . .	10	28¼	25	34	28½	11	17	22	20½
1st diameter . .	8·8	9·4	5·4	8·7	12·4	10·3	4·1	7·8	10·1
2nd diameter . .	8·9	9·7	5·4	8·4	11·8	10·3	4·3	8·3	9·8
Girth . . .	28	30	17½	27¼	38½	33	13¼	25½	31¾
1st diameter . .	4·2	9·0	7·9	8·3	8·7	7·1	7·9	7·0	3·3
2nd diameter . .	4·0	8·6	8·1	7·7	8·5	6·9	7·8	7·4	3·2
Girth . . .	13¼	27½	25½	25½	27¼	22½	25¼	22¾	10¼

1st diameter	9·9	4·2	10·4	5·7	11·3	5·6	9·3	5·6	5·4
2nd diameter	9·6	4·7	9·7	6·1	10·8	6·0	9·4	6·1	5·7
Girth	30¾	14½	32	19	35¼	18¾	29¾	18¾	17½
1st diameter	7·3	7·9	3·5	10·3	12·1	10·5	8·3	6·7	6·9
2nd diameter	7·1	7·5	3·7	10·4	12·2	11·0	7·7	6·4	6·6
Girth	23	24½	11½	33	38¾	34	25¼	21	21¼
1st diameter	4·5	5·9	7·7	5·6	11·0	8·2	4·4	6·9	7·3
2nd diameter	4·4	5·9	7·6	6·1	11·2	8·6	4·7	6·6	7·3
Girth	14¼	19	24¼	18¾	35	27	14¾	21¼	23¼
1st diameter	9·9	7·6	5·6	9·2	4·6	5·8	10·1	7·9	8·9
2nd diameter	10·0	8·6	5·9	8·5	4·7	6·5	10·4	8·2	9·0
Girth	31¼	25¾	18½	28	15¼	19¾	32¼	25½	28½
1st diameter	11·0	10·6							
2nd diameter	12·1	10·3							
Girth	36¾	32¾							

II. CALCULATING THE VOLUME OF A STANDING SAMPLE TREE.

The following recalculation of the example given in Macdonald's (6) paper entitled 'The Measurement of Standing Trees' may interest those who have not complete confidence in their ability to draw curves. It is based on Behre's (1) straight-line anamorphosis extensively used by Macdonald (5) elsewhere.

The data are given below.

Values of *l*, *g*, and *l*/*g* have been inserted, *l* being the length from tip to point of measurement divided by the length from tip to breast height, and *g* being the girth under bark at point of measurement divided by the under-bark girth at breast height.

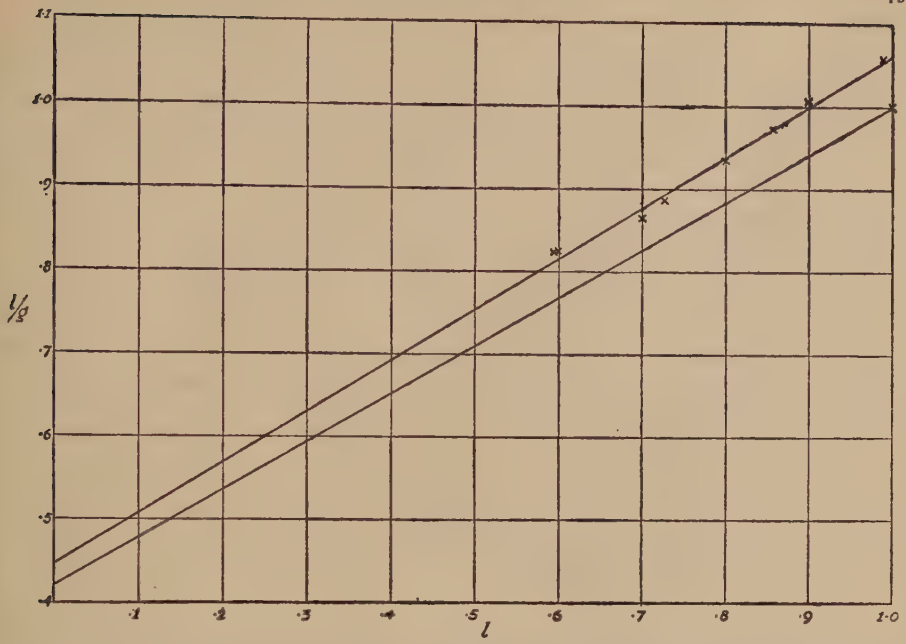
Total height of tree . . 80 feet
Girth over bark at breast height 49 inches
„ under „ „ „ „ 47 „

Point of measurement above ground-level

Ft. in.	*l*	*Girth under bark*	*g*	*l*/*g*
5 0	0·990	44	0·936	1·058
11 10	0·900	42	0·894	1·007
15 0	0·858	41½	0·883	0·972
19 5	0·800	40¼	0·856	0·935
25 0	0·726	38½	0·819	0·886
27 0	0·700	38	0·809	0·865
34 7	0·600	34¼	0·729	0·823
35 0	0·594	34	0·723	0·822

Values of *l*/*g* are plotted over corresponding values of *l*, and a straight line drawn through the points ignoring, if necessary, that corresponding to $l = 1{\cdot}0$.

The ordinate at $l = 1{\cdot}0$ is 1·060 in this trial: the actual girth under bark at breast height (47) is divided by this figure (1·060) to give the 'normal' girth under bark at breast height (44·3). The ordinate at $l = 0$ (0·446) is the uncorrected value of constant *a*; this value is divided by 1·060 to obtain the corrected value of *a* (0·421, and as the sum $a+b$ is equal to 1, $b = 0{\cdot}579$). Another straight line is drawn across the graph, joining ($l = 0$, $l/g = 0{\cdot}421$) with ($l = 1{\cdot}0$, $l/g = 1{\cdot}0$).



To obtain timber height, the under-bark girth at this point is conventionally taken to be 9 inches; this, when divided by the 'normal' girth of 44·3 inches, results in a value of g of 0·203. Entering the appropriate values of a, b, and g in Behre's formula $g = \frac{l}{a+bl}$ and solving for l gives 0·0969; this when multiplied by 75·75 feet gives 7·34 feet, or 7½ feet to the nearest half-foot, timber height being 7½ feet from tip or 72½ feet from ground-level. Under-bark girths are needed at 45 feet, 55 feet, and 66¼ feet—values of l are calculated corresponding to these heights above ground-level: corresponding values of l/g are read off the second straight line of the graph; corresponding values of g are calculated from these; and these values of g when multiplied by the 'normal' girth under bark at breast height give the required under-bark girths. The various steps are given in the following table:

Height above ground-level	l	l/g *(from graph)*	g	*Girth under bark*
45 ft.	0·462	0·688	0·672	29·8 in. (say 29¾ in.)
55 ft.	0·330	0·612	0·539	23·9 in. („ 24 in.)
66¼ ft.	0·182	0·527	0·345	15·3 in. („ 15¼ in.)

The volume of the tree is 44·48 cubic feet, 34·80 cubic feet being in the bottom four 10-foot sections (measured directly) and the balance of 9·68 cubic feet in the top three sections (estimated); the form factor is 0·419.

Macdonald's method has at least one advantage; use can be made, when extrapolating, of another point, $l = 0$, $g = 0$.

III. MEASURING TREES IN ONE LENGTH OR IN SECTIONS.

Chaturvedi (2) treats the error resulting from calculating the volume of a tree from one cross-sectional area measured at mid-length by reference to a solid generated by a curve whose general equation is

$$y^2 = px^r.$$

Percentage errors are given for selected values of r. Apart from the statement that the form factors of trees usually vary between 0·66 and 0·40, Chaturvedi appears to have made no generalization regarding stem form; the errors resulting from measuring trees possessing these form factors in one length are +5·7 per cent. and −13·1 per cent., which are the errors given in the list of selected values of r for $r = \frac{1}{2}$ and $r = \frac{3}{2}$ respectively; actually 0·66 and 0·40 are the absolute form factors of these solids.

Macdonald (5) reaches the following conclusions as regards stem form of conifers:

(1) . . . the under-bark form of the stem is substantially the same in all the important coniferous species in Great Britain. . . .

(2) The form of the stem in the various conifers agrees sufficiently well with Behre's theoretical curves, except in the upper parts of the stem. . . .

Davey (3) reproduces Chaturvedi's results and supplements them with a comparison of volumes of 50 conifers measured in 10-foot sections and in single lengths showing differences varying between ±4 per cent. His conclusions as regards stem form are—'As the majority of conifers tend to resemble the paraboloid form for the main part of their length . . . .' Davey also refers to Macdonald's work and draws his own conclusion in the following: '40 per cent. of the 2490 trees included in Macdonald's investigation came within Behre's form class 70. Their sectional and single length volumes differed by only 2%. 47% of the trees were divided between form classes 65 and 75. It may therefore be assumed that the paraboloid is the normal, or average, form of stem for conifers in Great Britain.' It may be noted that the form quotient of a paraboloid is $\sqrt{0{\cdot}5} = 0{\cdot}7071$, and the 'taper' very approximately 0·5556.

When it was learnt that the Forestry Commission Research staff was determining the error due to measuring a tree in one length (trade measurement), assuming that the 10-foot sectional volume (research measurement) is the nearest approach to the true volume available, a theoretical calculation was made of the sectional volume of a solid which conformed to Behre's formula but had the form quotient of a paraboloid:

Number of sections	*Volume (when length = 1)*	*Error %*
1	$\pi \times 0{\cdot}5000$	+2·29
2	$\pi \times 0{\cdot}4855$	−0·69
3	$\pi \times 0{\cdot}4863$	−0·52
4	$\pi \times 0{\cdot}4872$	−0·34
5	$\pi \times 0{\cdot}4877$	−0·23
10	$\pi \times 0{\cdot}4886$	−0·05
20	$\pi \times 0{\cdot}4888$	..

The error is based on the 20-section volume. As another approach, the mean form quotient of Macdonald's published figures for distributions by form classes was calculated (excluding 8 Western American larch and 25 Western Hemlock spruce). The value for the total with its standard error is $0{\cdot}69495 \pm 0{\cdot}001044$, hence it differs significantly from the form quotient of the paraboloid. For the important species, true volumes of solids of unit lengths with Macdonald's average form quotients were integrated,* and the single-length volumes compare with the true volumes as follows:

	Norway spruce	*Scots pine*	*Corsican pine*
Single-length volume	$\pi \times 0{\cdot}5329$	$\pi \times 0{\cdot}5141$	$\pi \times 0{\cdot}5041$
True volume	$\pi \times 0{\cdot}5094$	$\pi \times 0{\cdot}4976$	$\pi \times 0{\cdot}4914$
% difference	$+4{\cdot}62$	$+3{\cdot}31$	$+2{\cdot}58$
	Sitka spruce	*European larch*	*Douglas fir*
Single-length volume	$\pi \times 0{\cdot}4984$	$\pi \times 0{\cdot}4816$	$\pi \times 0{\cdot}4442$
True volume	$\pi \times 0{\cdot}4879$	$\pi \times 0{\cdot}4776$	$\pi \times 0{\cdot}4543$
% difference	$+2{\cdot}15$	$+0{\cdot}85$	$-2{\cdot}21$
	Japanese larch	*All important species*	
Single-length volume	$\pi \times 0{\cdot}4396$	$\pi \times 0{\cdot}4878$	
True volume	$\pi \times 0{\cdot}4518$	$\pi \times 0{\cdot}4814$	
% difference	$-2{\cdot}72$	$+1{\cdot}33$	

The approach is completed by the following:

Form quotient	0·70711		0·69495	
Number of sections	*Volume*	*Error %*	*Volume*	*Error %*
1	$\pi \times 0{\cdot}5000$	$+2{\cdot}27$	$\pi \times 0{\cdot}4830$	$+0{\cdot}95$
2	$\pi \times 0{\cdot}4855$	$-0{\cdot}71$	$\pi \times 0{\cdot}4737$	$-0{\cdot}99$
3	$\pi \times 0{\cdot}4863$	$-0{\cdot}53$	$\pi \times 0{\cdot}4753$	$-0{\cdot}64$
4	$\pi \times 0{\cdot}4872$	$-0{\cdot}36$	$\pi \times 0{\cdot}4764$	$-0{\cdot}41$
5	$\pi \times 0{\cdot}4877$	$-0{\cdot}25$	$\pi \times 0{\cdot}4771$	$-0{\cdot}28$
10	$\pi \times 0{\cdot}4886$	$-0{\cdot}07$	$\pi \times 0{\cdot}4780$	$-0{\cdot}08$
20	$\pi \times 0{\cdot}4888$	$-0{\cdot}02$	$\pi \times 0{\cdot}4783$	$-0{\cdot}02$
True volume	$\pi \times 0{\cdot}4889$		$\pi \times 0{\cdot}4784$	

Permission has been given by the Chief Research Officer of the Forestry Commission to reproduce the following extract from an unpublished report:

'In the Permanent Sample Plot work the practice hitherto has been to measure all sample trees and thinnings in 10-foot sections over and under bark. This was laid down in the original instructions to conform to the continental practice of measuring all sample plot trees in sections, though they use shorter sections, usually of one metre. In our work it has

* The volume obtained by rotating the area under $y = \frac{x}{a+bx}$, when $a+b = 1$, between $x = 0$ and $x = 1$ around the x-axis is

$$\frac{\pi}{b^3}(b+ab+2a\log_e a).$$

fortunately been the practice to measure sample trees also at half timber height so that the data are available for comparing the two methods of measurement. A number of species have been recently investigated with the following result.

Species	*Number of trees*	*Difference between 'half timber height' volume and 'sectional' volume as a percentage of the 'sectional' volume. Under-bark %*
Scots pine . .	428	+0·7
European larch . .	294	+1·0
Norway spruce . .	171	+4·3
Corsican pine . .	464	+5·0
Japanese larch . .	751	+1·0
Sitka spruce . .	103	+2·3
Douglas fir . .	386	−1·4

It is apparent from the above table that the average difference between the two methods of measurement is negligibly small except possibly in the under bark volumes of Norway spruce and Corsican pine. It is also interesting to note that practically all the differences are positive, that is to say that in most of the species examined measurement at half timber height gives slightly larger volumes than measurement in 10-foot sections, a result which was quite unexpected. In economic forestry, measurement is always at half timber height, in conifers; sectional measurements take up a great deal of time; the shorter the sections the greater the experimental error; lastly, there is no such thing as a 'true' volume for any given tree, the volume varies with the method of measurement and there is no absolute standard. For the above reasons it is considered justifiable to abandon sectional measurements, at any rate during the present war, and to girth all sample trees and thinnings in future at half timber height only. The saving in time, above all in the case of standing sample trees, will be very appreciable.'

The arithmetic mean of these results, using Macdonald's numbers of trees as weights, is +1·47 per cent., but these percentage errors are not strictly comparable with those derived from theoretical solids; the latter when applied to trees comprise the portion from breast height to tip; the Forestry Commission volumes refer to the portion from ground level to a timber height of 3 inches diameter over bark.

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THE OCCURRENCE OF *MELAMPSORA PINITORQUA* ON SCOTS PINE IN SOUTH-EASTERN ENGLAND

BY T. R. PEACE

IT may be worth putting on record that the fungus *Melampsora pinitorqua* Rostr. has been found doing appreciable damage to young Scots pine over limited areas in four places in Kent and Sussex. This fungus has usually been considered as rare in this country, and it is therefore surprising to find it causing such severe damage that in one case the clearing and replanting of the infected area was considered, a proposal since modified in view of a very marked reduction in the violence of the disease.

The disease was first noticed in the autumn of 1942 on two patches of about 1 acre each at Vinehall Forest near Battle, Sussex, and at Lyminge Forest between Folkestone and Canterbury, in Kent. At Vinehall the trees were planted in 1937 and at Lyminge in 1938. The trees were festooned with shoots which had died during the previous summer, and at first the damage was thought to be due to pine shoot beetle. The fact that the injury was more or less limited to a small area in a much larger plantation led to further investigation, and it was found that the dead shoots had not been tunnelled and that many apparently uninjured shoots had small cankers on them. At this time of year there were no obvious signs of fungal infection, and it was considered that the injury might have been due to some mechanical cause, such as a severe local hailstorm, though no records of such phenomena existed.

But in the middle of May 1943 typical fresh cankers, with quickly developing caeomata of the fungus *Melampsora pinitorqua*, appeared abundantly at both areas. It was found that the alternate host, aspen (*Populus tremula*), occurred abundantly mixed with the pine on both areas. It had been cut down periodically when the pine were weeded, so it was only about half the height of the pine. In early June *uredosori* were abundant on the aspen leaves. It was suggested by Massee, quoted by Grove (1), that the aecidiospores can reinfect the pine and perpetuate the disease without the alternate host, but there is no proof of this. Grove states that the mycelium is almost certainly perennial in the infected branch. Nevertheless, it was hoped that by cutting the aspen, and thus reducing the teleutospore production, the number of fresh lesions in 1944 might be reduced; and in both areas the aspen was cut as low as feasible during July.

In July 1943 the disease was found on a plantation of Scots pine planted in 1939 on Great Sanders estate, property of Hastings Corporation. This area was only a few miles from the one at Vinehall. By the end of 1943 it was apparent that the disease at Vinehall and Lyminge had not done as much damage that year as in 1942. The disease was on a much smaller scale in 1944 than in 1943; indeed, at Vinehall and Lyminge it was not possible to find any current year's lesions during a very quick survey, though the deformation which had occurred in

previous years was still clearly visible. At Great Sanders the lesions could still be found, though in much smaller numbers. It is not known to what extent the absence of the disease at Vinehall and Lyminge can be attributed to the cutting of the aspen; but in view of the marked reduction at Great Sanders, full credit obviously cannot be claimed.

In 1944 the disease was found at Hemsted Forest near Benenden, Kent, on Scots pine planted in 1941. The damage here was slight, and what there was had occurred much more in previous years, probably chiefly 1943, than in 1944. The area was still subject to annual weeding, so the aspen would have been cut every year as a matter of course.

While it was quite definite that aspen occurred abundantly in the infected areas, it was not possible to investigate the distribution of aspen in the plantations in relation to the distribution of the disease. It was, however, certain that aspen did occur in some places where the disease was absent both from the pines and from the aspen.

Injury, in the form of loss and deformation of shoots—particularly of leaders—was really serious in 1942, and, if it had continued on that scale, it would have rendered the plantation valueless in three or four years, making replanting, presumably with another species, essential. As it is, unless there is a recrudescence, it has become merely a matter of interest that a rare fungus should appear so suddenly and violently in quite widely scattered areas.

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ON THE IMPORTANCE FOR FORESTRY OF THE STUDY OF SYSTEMATIC MYCOLOGY*

BY W. R. DAY

(*Department of Forestry, University of Oxford*)

THERE has been much discussion in informed circles on the present unsatisfactory position in this country with regard to the facilities at present existing for the study of the taxonomy and nomenclature of fungi. These are undoubtedly very inadequate. There are a very few experienced systematic mycologists in London, at the Kew Herbarium, the British Museum, and the Imperial Mycological Institute. There remain besides a few University teachers and a very limited number of applied mycologists and expert amateur mycologists interested in systematy. The time which these collectively have to devote to research into the systematy of fungi is completely inadequate, not merely for the proper development of mycology as a pure science, but also for its efficient application to the needs of our economic life. Those who are acquainted with modern developments will know of the important connexions between medical science, the general study of plant pathology, and certain industrial activities in which fermentation processes form an essential part. Ecologists will also be aware of the tremendous lack of knowledge with regard to the fungi which form an inevitable and important part of the associations of plants and animals which make up our fields and forests. Under these circumstances it is not unimportant for us to ask what is the place of systematic mycology in forestry and what should be done to ensure that there are adequate facilities for its study for forestry purposes.

It should be realized, first of all, that taxonomy and nomenclature are studied as means to an end and not as ends in themselves. The means will inevitably be neglected if the ends to be achieved are lost sight of or perhaps misunderstood. The efficient practice of forestry rests fundamentally on its biological side, upon a knowledge of the constitution of the associations of plants and animals which form the forests, and of the inter-relationship between the various members of them. It is quite impossible to develop such knowledge adequately without an understanding of the fungi, and one cannot even begin to talk about these intelligently until some suitable system of classification and nomenclature has been devised. This is the fundamental case for the support by foresters of systematic studies in mycology. A similar argument may be developed for those industries which use forest products. The truth is that the forester cannot work as efficiently as is desirable, either silviculturally or economically, unless the fungi are adequately named and classified. Without this, one of the tools necessary for efficient working is missing.

Whatever section of forestry activities one takes, the argument is fundamentally

* A note on an *unpublished* report by a Committee of the British Mycological Society on 'The Need for Encouraging the Study of Systematic Mycology in England and Wales'.

the same. Great stress is laid, for example, on the necessity of systematic studies in mycology for progress in forest pathology. It is also stressed that all pathologists should have a thorough grounding in fungus systematics. A word of warning may be given here: the pathologist needs to be an adequate physiologist, general field ecologist, pedologist, bacteriologist, and perhaps a few other things, as well as systematic mycologist. This is particularly true of the forest pathologist at the present time. He needs, in some ways, to specialize in not being a specialist. So long as these conditions prevail it is quite impossible for him to maintain himself adequately as a systematic mycologist. All the more abstruse and difficult systematic problems, at least, must necessarily be worked out for him by specialists, or should be. At present such specialists either do not exist or have no adequate time to give to his particular needs.

A similar argument could be developed with regard to the study of fungus ecology in forestry. This is an important but greatly neglected study. It will never be possible to develop it adequately until more attention is paid to systematics.

How is this present unfortunate situation to be remedied? The remedy is to be found in the realization of what is necessary for the proper development of biological knowledge in forestry. No one pays for a tool for which he has no sense of need. The first thing, obviously, is for foresters to realize that the tool is needed. This can only come about by understanding how essential to efficient forestry is a knowledge of the constitution and inter-working of the body of organisms of which the forest is composed. How many foresters are unable to see the wood for the trees! And fungi are an essential part of the wood though for the most part little seen or thought about. Thought and discussion along these lines can be heartily recommended to those responsible for forestry research and for the general management and development of our woodlands. Systematic mycology can receive nothing but good from such activities and well deserves to do so.

SOCIETY'S AND OTHER NEWS

FINANCES

At a Council Meeting held in Edinburgh on 11 July 1944 the audited accounts for 1943 were adopted, the credit balances being: General Fund, Capital £386. 3*s*. 1*d*., Revenue £338. 12*s*. 10½*d*.; Medal Fund £22. 18*s*. 2*d*.; Excursion Fund £22. 12*s*. 4*d*. As in 1942, the capital balance, the bulk of the Revenue balance, and the whole Medal and Excursion Fund balances were in Edinburgh Savings Bank and thus on loan to the Treasury.

MEMBERSHIP

During 1943 several members who had allowed their membership to lapse during the early years of the war were reinstated and there was a very good addition of new members, bringing the total up to 159 at the end of the year. Further additions since the beginning of 1944 had raised the total to 174 by mid-October 1944.

APPEAL FOR BOOKS

The Conference of the Allied Ministers of Education has appealed to the members of our Society for help in the restoration of national, university, public, and other libraries in Allied countries, and this appeal hardly needs any commendation. Books of all kinds are required, but there is a special need for modern technical and scientific works. Any members who can spare such books in good physical condition are asked to send them to the Inter-Allied Book Centre, 3–5 Salisbury Square, London, E.C. 4.

THE LATE MR. A. WARREN

We regret to record the death of Mr. A. Warren, which took place suddenly on 17 October 1944, in his 60th year. He had been a Fellow of this Society since 1929. He resided in Morayshire for about 20 years, first as a Head Forester in both private and State forests, and since 1934 as District Officer in the Forestry Commission. He was seconded for Timber Production at the outbreak of war. Morayshire is one of the most important forest districts in Great Britain, both from the private and State forestry points of view, and Mr. Warren came to epitomize forestry in this district in the eyes of all classes, the lairds, factors, foresters, forestry workers, and the general public. It was an ideal state of affairs, and might well be the model for the whole country, because if it prevailed there would be less likelihood of conflict between State and private forestry interests, and those representing them.

He was a practical forester in the best meaning of that term. No practical problem, not even the Teindland soils, amongst the most intractable in the country, or the manifold difficulties of war-time timber production, daunted him.

His two dominant personal qualities were first his great capacity for work freely given in the cause of forestry, and secondly his interest in all known to him. He not only knew every worker in his charge, but was the friend of each. Moreover, his wife and he were most hospitable, and his house in Elgin was a meeting-place for foresters. The sympathy of many members of this Society who enjoyed his friendship and hospitality will go out to his widow and family in their bereavement.

THE LATE PROFESSOR J. H. PRIESTLEY, D.S.O., B.Sc.

Joseph Hubert Priestley, Professor of Botany in the University of Leeds since 1911, died on 31 October, 1944, aged 61. Priestley was one of the most gifted and original botanists in this country in the fields of plant physiology and developmental anatomy. Moreover, he was one of the most stimulating of men, and a charming companion. Some twenty years ago he became interested in the growth of trees, and he and members of his staff, inspired by him, carried out a series of important researches on different aspects of this subject. Some of this work was too technical to be published in this journal, but he wrote two simplified articles entitled 'The Growing Tree' and 'Radial Growth and Extension Growth in the Tree', which were published in volumes VI and IX respectively. His work in this field attracted more attention in America than in this country, and shortly before his death he expressed regret that he had not simplified it sufficiently to be appreciated generally by foresters. Two members of his staff, Preston and Misra, published articles more recently in this journal.

Until the end Priestley continued to probe the problems of developmental anatomy of trees, and by his death forestry loses one of its most distinguished investigators. Although he was not a member of this Society, members will, therefore, wish to pay tribute to him and the work he has done.

REVIEWS

Problems in Tree Nutrition. By M. C. Rayner and W. Neilson-Jones. Faber and Faber Limited, 1944. 12*s.* 6*d.*

Review by W. H. Guillebaud

In this volume are republished four papers by Dr. Rayner which appeared in the following numbers of *Forestry*: vol. viii, No. 2, 1934; vol. x, No. 1, 1936; vol. xiii, No. 1, 1939; and vol. xv, 1941; Dr. I. Levisohn was a co-author of the last of the above papers. The volume also includes the paper by Professor Neilson-Jones published originally in the *Journal of Agricultural Science*, vol. xxxi, No. 4, 1941, under the heading 'Biological Aspects of Soil Fertility'. The writers have added a 10-page Introduction to the five papers together with a Glossary and Index; Professor H. M. Steven has provided a Foreword.

The book is a progressive record of researches continuing over a period of more than 10 years, presenting, as the title-page puts it, 'An account of researches concerned primarily with the mycorrhizal habit in relation to forestry, and with some biological aspects of soil fertility'.

The introductory Chapter I forms an admirable background to the original articles. It begins with a general statement on the ecological background of forestry, stressing the obvious but often overlooked fact that, in the words of the authors, 'cultivation of any crop is an attempt to create an artificial ecological unit of vegetation', and pointing out the fundamental difference between the short-lived agricultural crop and the unit composed of a phalanx of forest trees. There follows an illuminating account of the mycorrhizal habit in trees with special reference to the pioneer researches of Frank and Stahl, an account which is elaborated in subsequent chapters. The long-standing controversy on the physiological significance of the mycorrhizal habit is touched upon, and it is pointed out that the tendency of plant pathologists has been to regard all fungi invading or mantling the root tissues as pathogens, filching, from the plants 'attacked', supplies of organic and other nutrients. It may be observed that Rayner's researches go far to demonstrate the crudity of such a view-point. The three chapters which succeed the Introduction describe and discuss Dr. Rayner's investigations on what may be termed the Wareham Soil Problem.

The problem as it appeared in 1929, the datum year for this work, was how to account for the patchy and, in general, unsatisfactory condition of extensive direct sowings of various species of pines carried out by the Forestry Commission between 1924 and 1927. The sowings were made in patches formed by removing a small square of turf, slightly stirring the exposed mineral soil, putting in a pinch of seed, and covering with a little loose soil. The seed mostly germinated quite well, so that at the end of the first growing-season the operation looked successful; in the second year there was little change to report; the seedlings were mostly alive, but few had made any appreciable growth. By 1929 the condition of the earlier sowings was a deplorable one: the seedlings in many of the patches had died out; where they had survived the majority had made little or no growth. Only here and there individual seedlings, and sometimes whole patches, had begun to grow at a more or less normal rate. What were the factors which accounted for these extensive failures, and was there any treatment which would improve the conditions sufficiently to enable successful plantations to be raised?

The Commission's staff together with their Research Branch tackled the practical side of the problem by ploughing up the ground, using strong tractor-driven ploughs, and then

planted the area with transplants of Scots pine and Corsican pine. Other species were tried experimentally, basic slag was applied to some of the plots, and there were further experiments with direct sowing of pines on the ploughed ground, trying various manures such as lime, basic slag, and bone-meal. The results on the whole have been fairly successful; the improved drainage and aeration resulting from the ploughing have enabled the young pine plants to establish themselves, and though growth has been slow the plantations are mostly fully stocked. Time alone will show whether the present progress of the plantations will be maintained, but there are no grounds for serious pessimism at the moment. The practical solution of an afforestation problem is one thing, its theoretical solution, as a careful study of the work under review demonstrates most clearly, is quite another. It was Dr. Steven, then Research Officer for England and Wales, who, suspecting that a clue to the trouble might lie in the mycorrhizal habit of the pines used, induced Dr. Rayner to investigate the matter on behalf of the Forestry Commission.

In Chapter I, page 37, Rayner outlines the nature of the problem as it first appeared to her, the working hypothesis being that the failure of the seedlings to grow was due to malnutrition as a result of inability to form mycorrhizas. Rayner's previous study of the function of the mycorrhizal habit had convinced her that 'the conversion of a large proportion of the sub-lateral root system into mycorrhizas is a natural and inevitable habit in the pines studied, and the formation of healthy and functional mycorrhizas is regarded as a formal condition for nutrition and growth under woodland conditions, there being a direct causal relation between healthy mycorrhizas and thrifty growth'.

The inability of the Wareham seedlings to form mycorrhizas might be due to such causes as absence of the mycorrhiza-forming fungi from the Wareham soil, or toxicity, and the remainder of Chapter II describes and discusses the critical experiments carried out to investigate these assumptions. The toxicity aspect was studied in part by experimental applications to the soil of specially prepared composts. This compost work, which bulks so largely in the remaining chapters of this book and has proved so successful and illuminating, was based on a very original working hypothesis. In the first place it was considered by Rayner that the cause of toxicity was likely to reside in the nature of the raw humus formed in the Wareham soil; secondly, that it was possible that the trouble was associated with some upset in the normal process of humification. Normally, cellulose is attacked first and broken down in the humifying process, but from observations made on the bad effect on tree growth of adding cellulose to an otherwise good soil and of the good effect of covering the soil below trees with twigs and branches (*Reisigdüngung*), Rayner got the brilliant notion of applying to the soil a well-decomposed compost which would be rich in lignin and contain very little cellulose. Whatever criticisms may be directed against the hypothesis, the fact remains that it worked. Further work in the toxicity problem is described in detail in Chapter VI, and we shall come to this in due course.

Chapters III and IV recount the pioneer investigations with different types of compost. Reading the account of these elaborate and necessarily involved researches the outstanding impression is of the delicacy of the reactions and of the complexity of the whole business. The composts were all made out of dead vegetable matter, spent hops, straw, sawdust, birch leaves, &c., and available nitrogen applied in the form of dried blood and in various inorganic substances such as ammonium sulphate and ammonium phosphate, and yet the results varied with the species of tree and with the particular kind of compost. The differences in the chemical composition of the composts seem inadequate to account for the varied reactions on the part of the seedlings. Analysis shows that the composts contain substantial quantities of N.P.K.; but that their effect upon growth is primarily due to their content of available nutrients appears unlikely in view of the data given in Tables IV and V on pages 72

and 73, which give the result of pot experiments with tomatoes, wallflower, tobacco plant, and other flowering herbs, as well as with Scots pine. The evidence as to the *modus operandi* of the composts is marshalled in Chapter IV, where the conclusion arrived at was that the action of the compost in stimulating the growth of pine seedlings differs essentially from that of ordinary manures and that the beneficial effect is closely bound up with the mycorrhizal habit of the pines. The views expressed in the earlier papers that there were toxic substances present in the Wareham soil were held to be confirmed.

For the purpose of this review it seems most convenient to pass on now to Chapter VI which describes Neilson-Jones's investigations on the toxicity of Wareham soil and on the methods of removing the harmful substances present. An interesting feature of this work has been the discovery of a highly ingenious technique for testing soil toxicity. This technique, which was initiated by A. G. Morton and improved and developed by Neilson-Jones and Levisohn, is the nutrient-agar-film test method and consists in preparing a glucose agar medium with an acid reaction; the soil sample to be tested is placed in a Petri dish and the liquid agar, just before setting, poured over the soil to form a thin film. The open dish is exposed to the air and, if the soil sample is normal, the agar-film soon becomes covered with a profuse growth of Penicillium and other moulds.

Wareham soil, on the other hand, was found frequently to inhibit any development of moulds in the surface of the agar film. Partial or complete sterilization of Wareham soil destroyed the toxic principle, but the latter could be reinduced by soaking in water partially sterilized (but not completely sterilized) soil. This and other evidence led Neilson-Jones to conclude that the toxicity is of biological origin and most probably due to an anaerobic sulphuretted-hydrogen-producing bacterium. After applying compost to the soil the toxicity was completely removed when tested by the nutrient-agar-film method.

On pages 162 and 163 Neilson-Jones discusses the origin and nature of the improvement brought about in the Wareham heath soil as a result of adding compost, and suggests that there are at least four factors working concurrently: (1) removal of toxicity; (2) addition of mineral nutrients which are contained in the compost (there is a good deal of negative as well as positive evidence to show that this is unlikely to be a major factor); (3) addition of growth-promoting substances of fungal origin (the evidence for this is not complete); (4) alteration in the constitution of the organic substrate. The last-mentioned factor would seem to be a natural consequence of the first of the four factors because removal of the principle inhibiting fungi activity in the soil might be expected to result in the fungi setting to work on the humus and breaking it down.

Before leaving the subject of the composts and their effect in stimulating the growth of pines on Wareham Heath a few observations on the practical developments may be useful. As already remarked, the various composts applied differ in their effect upon growth; by far the best early response is obtained by applying Compost C5, which is made from hop-waste, composted with ½ per cent. or 1 per cent. nitrogen (in terms of dry hop-waste) applied in the form of dried blood. Several acres previously ploughed have been sown experimentally at Wareham with pines, using patches spaced 4½ feet apart, with 2 lb. of C5 compost worked into each patch. The result has been remarkably successful, especially with Corsican pine, and the plantations so formed are outstanding for health and vigour. The method is, however, costly not only in the initial formation, but also in the subsequent tending, because the seedlings have to be gradually singled out.

The 1-year pine seedlings produced in these patch sowings are so much larger and, more specially, better rooted than seedlings of the same age raised in permanent nurseries at Ringwood and in the New Forest, which are also on soils of the Bagshot Sands, that it seemed an obvious development of the method to form rough nurseries on ploughed-up

Wareham Heath soil, sowing trees in the normal way after digging in the standard application of compost at the rate of 10 lb. per square yard. This work was started at first on a very small scale but has gradually developed, in close collaboration with Dr. Rayner, and other species such as Sitka spruce, Norway spruce, Thuya, Tsuga, and birch have been sown in addition to the pines. The method has also been extended to other areas including a woodland soil near Oxford, and moorland soils near Scarborough in Yorkshire. Difficulties in obtaining sufficient hop-waste have led to the trial of other composts in which bracken, sawdust, or straw are used as the vegetable base. It is a curious fact that success with all species has been greatest at Wareham, though this is the only soil which, in its natural unimproved state, contains a toxic principle. Seedlings raised on compost-treated Wareham Heath soil are much larger and better rooted than those which are raised in the majority of our permanent nurseries. The difference varies with the species but is greatest in the case of Sitka spruce and Norway spruce; an average 1-year-old Sitka spruce seedling raised in an ordinary permanent nursery is usually between ¾ inch and 1 inch in height; the corresponding seedling raised on Wareham soil treated with hop-waste compost is 2 to 2½ inches in height, and is large enough to handle and line out to produce 1-year-1-year or 1-year-2-year transplants. One-year seedlings of pines, Thuya, and Lawson cypress raised at Wareham are correspondingly sturdy and can be lined out with complete success. This is an interesting and potentially important development which obviously raises a number of questions relating to tree nutrition and the correct treatment of the soil in permanent nurseries. These are under investigation at the present time.

Work still remains to be done before the method can be considered as beyond the experimental phase; to take an example, it is not yet known how long such a soil as Wareham will continue to produce good tree seedlings or how it should be treated to maintain its fertility.

One feature of special interest in these composted wasteland nurseries is that there is little or no development of annual weeds in the seed beds. Weeds are the bane of the existence of the average forest nurseryman, especially in war-time when the shortage of labour is so acute. However careful the weeders may be, many small tree seedlings are lost in the process of weeding, and the saving in plants, as well as in labour, by working with a wasteland soil is a very substantial set-off against the other costs of the method.

The justification for this somewhat lengthy digression from our theme is that it may serve to illustrate the truth that practical applications of so-called 'pure research' are often only just around the corner. In this particular case, the outcome of the study of tree growth on a very exceptional soil may lead to far-reaching developments in forest nursery practice.

To return now to the work under review, Chapter V, headed 'Studies in Mycorrhizal Response in Pines and other Conifers', is a comprehensive survey of the information on this subject gained from the field studies and pot experiments carried out with tree plants raised in Wareham soil. It is highly condensed, contains a wealth of original material, and forms a major contribution to the study of mycorrhizas. It was a fortunate chance which directed Rayner to the Wareham Heath, because, owing to the special properties of that soil, the observation of mycorrhizal relationships is simplified, notably owing to the absence of the fungi which in other and better soils are liable to parasitize the roots or produce those pseudomycorrhizas which are such complicating features in the picture. The first and longest section of Chapter V deals with the pines; these are discussed under the headings of (*a*) Mycorrhizal associations, (*b*) Pseudomycorrhizal or deleterious associations, and (*c*) Experimental soil treatments. The chief mycorrhiza-former of Scots and Corsican pine at Wareham is proved to be *Boletus bovinus*, and the structures are described in detail and figured with microphotographs. Where soil conditions are unfavourable what

the authors term aberrant structures appear and these also are described and figured. An interesting discovery was the proof of the identity of rhizomorphs, which occur frequently in the soil at certain times of the year, as forming a resting-stage of *B. bovinus*. Another fungus which forms a different type of mycorrhiza is *Mycelium radicis nigrostrigosum*, but this appears to have been introduced with humus inocula brought by Rayner from outside the Wareham area. This fungus and another, *Rhizopogon luteolus*, which has recently appeared in certain of the treated plots at Wareham, form quite distinct mycorrhizas from those of *B. bovinus*. Whether the introduction of mycorrhiza-formers which are not native to the area is advantageous or not is a point on which the authors do not express an opinion. In the course of time evidence on this point will doubtless become available.

Pseudomycorrhizal associations of pine are next discussed, and it seems clear that these are due to distinct species of fungi and not to any of the true mycorrhiza-formers, that is to say a pseudomycorrhiza is not due to a *Boletus bovinus* association going wrong, so to speak, but to the attack of another fungus; in the case of the pines it is usually a fungus named *Mycelium radicis atrovirens*. Pseudomycorrhizas caused by this fungus are common features of pines raised in permanent forest nurseries.

The addition of compost to Wareham soil produces a pine seedling with a very bushy root system with great numbers of short roots; the latter are at first entirely non-mycorrhizal, i.e. free from fungal infection, but towards the end of the first growing-season all the short roots become mycorrhizal by association with *Boletus bovinus*, the roots become lighter in colour and the shoots elongate. The preliminary stimulus to root development which takes place in compost-treated soil also occurs when active humus inocula are introduced, or when the soil is inoculated with a pure culture of *Boletus bovinus*; this stimulus may be due to some excretion (growth-promoting substance) from the fungal mycelium introduced, or activated by the compost.

The section dealing with the pines is succeeded by observations on similar lines dealing with Sitka spruce and Norway spruce, with a shorter note on Lawson cypress. In addition to two forms of *M. R. atrovirens*, a third fungus of a *Rhizoctonia* type has been found to cause pseudomycorrhizal structures in Sitka spruces. Some interesting experiments on the introduction of humus inocula from native stands of the two spruces are described. In both species pseudomycorrhiza-forming fungi were introduced with the humus inocula with harmful results when seedlings were raised in Wareham soil. These experiments demonstrate clearly the risks involved in the use of humus inocula and probably explain the conflicting results obtained in practice from endeavours to inoculate nursery soils by applying forest humus.

Chapter V continues with a brief section on technique, of special interest to mycologists and to research workers raising small trees in pots under glass, and concludes with a discussion of the functional part played by mycorrhiza in the development of the young conifer raised from seed on Wareham heath soil. The authors' conclusions are stated as follows: 'Lack of correct mycorrhizal equipment is here (i.e. at Wareham) associated invariably with symptoms of starvation, arrest of growth, and progressive discoloration or chlorosis of the needles—the latter especially in certain species, notably Norway spruce. Mycorrhizal activity, manifested as an annual crop of short roots that become mycorrhizas, whether induced by soil treatments or by the introduction of specific mycorrhiza-formers as soil inocula or pure cultures, is followed immediately by relief of these symptoms, rapid greening of the foliage and resumption of active growth.' The authors further express the view that there is an ecological balance between the higher plants and their fungus competitors in the soil, and that the mycorrhizal association is a specialized aspect of this balance.

It would seem, then, that the problem for the forester is to manage his woodlands in

such a way as to maintain an ecologically balanced condition of the soil, one important index to his success being the nature of the mycorrhizal structures formed; if these structures are normal, soil conditions may be assumed to be satisfactory, but if abnormal, the forester may take it as a warning that the delicate ecological balance of the soil has been upset, and he may be able by thinning, or some other silvicultural practice, to improve the conditions.

Even a casual study of current forestry literature shows that all over the world forest research workers and foresters are taking an increasingly active interest in tree mycorrhizas, and there is a growing realization that these remarkable structures, far from being mere botanical curiosities, are vital to the tree in its normal habitat, and play an essential, though still largely unexplained, part in tree nutrition. The work under review is unquestionably a major contribution to the problem and we should like to congratulate the publishers as well as the authors on their enterprise in presenting these records to the public in such a compact and convenient form.

The volume contains a comprehensive list of references and there is a glossary. The latter will be greatly appreciated by those foresters whose memory of technical botanical terms may have become rusty in the course of their professional service.

British Woodland Trees. By H. L. Edlin. B. T. Batsford Ltd., London, 1944. Price 12*s.* 6*d.*

Review by T. R. Peace

THIS book is in the main a practical description of the trees occurring naturally or planted for forest purposes in Great Britain; some attention is also paid to woodland shrubs and to the commoner trees used for ornamental, rather than forest, purposes. Brief notes are also given on the methods of cultivation and uses of each tree. Six additional chapters deal very briefly with broad-leaved and coniferous trees considered as contrasting groups, forest practice, silvicultural methods, woodland types, and so on. In view of the fact that the information in these chapters is hopelessly condensed and that one chapter consists largely of unanswered questions, it is a pity that there is no bibliography. Keys for the identification of trees at different times of year are given, and, though for the more difficult genera these go no further than the genus, and in other genera only include the commoner species, they will certainly assist students to familiarize themselves with the commoner trees.

The book is illustrated with photographs, which are both decorative and descriptive, with 32 full-page plates of foliage and flowers reproduced from John Evelyn's *Silva* (which have suffered by a reduction in size, being somewhat gloomy and obscure in detail), and with some line drawings, the best of which show what might have been done for other species instead of the *Silva* illustrations, the worst of which show very little at all.

It is a pity that the mass of useful and on the whole well marshalled information given in the text is marred by too frequent inaccuracies, such as the statements that the side buds on the terminal shoot of a conifer are usually four in number, that ash leafs so late that frost damage is rare, that elm disease in its earlier days killed out all the trees infected, and the inference that the mycorrhizal habit is restricted to conifers.

This book does fill a gap in forest literature and it is to be hoped that later it will be possible to reissue it with improved line illustrations, a bibliography, and inaccuracies corrected.

The publishers have maintained the high standard in production which they have set themselves, in spite of war-time difficulties.

The Virgin Upland Forest of Central New England. A Study of Old Growth Stands in the Pisgah Mountain Section of South-western New Hampshire. By A. C. CLINE and S. H. SPURR. Harvard Forest Bulletin No. 21. 58 pp., illus. Petersham, Massachusetts, U.S.A., 1942. Price 50 cents.

Review by BARRINGTON MOORE

CLINE and Spurr's *The Virgin Upland Forest of Central New England* not only maintains the high standard of the Harvard Forest publications but is of unusual interest for several reasons. In the first place it is a careful study of the results of natural processes free from human interference, and therefore affords a sound basis for developing silvicultural methods which will follow and work with nature rather than against it. The study fits in with the experiments carried out on the Harvard Forest under the directorship of the late Dr. Richard T. Fisher, to find the reasons for the failure of many of the efforts to grow white pine (*Pinus strobus*) in a region in which this valuable tree is extremely abundant. Secondly, it preserves a permanent record of one of the last remnants of the forest which originally covered large areas in north-eastern United States. The record was made none too soon, and is now of special value because this remnant was blown down by the hurricane of September 1938, which swept over New England, destroying the forests on literally hundreds of thousands of acres. Lastly, the results of this study change our ideas concerning the character of virgin forests.

New England has had an interesting forest history. Covered with almost continuous forest when the white man arrived in the seventeenth century, by the early part of the nineteenth century 70 per cent. of the forests had been cleared for cultivation. With the opening of the richer farming-lands farther west, agriculture in New England declined, and the fields reverted to forest through natural seeding in from the sides, until towards the latter part of the nineteenth century the position had been reversed, and 70 per cent. of the area was under forest. White pine took possession of these abandoned fields and covered large areas throughout the region. Although the timber was of poorer quality than that from the large old white pines because of its smaller size and many knots, nevertheless it was so good for box boards and other uses that an active market developed for it and the old field stands brought high prices. As they showed rapid growth and high yields, what could be more natural than that foresters should recommend planting white pine as the most profitable timber crop?

Trouble developed before long, but not before a good deal of money had been wasted on plantations that turned out to be expensive failures. The principal reason was that these plantations were made against the 'silvicultural stream' or natural trend. Most of the abandoned fields were on hardwood land on which the natural forest was hardwoods with a scattering of white pine in mixture, and the pine which took possession was only a stage in the succession towards the hardwood climax. Consequently the planted pines were soon overgrown and smothered by broad-leaf trees, some of which had even started under the stand of old field pine before it was cut. There were also other difficulties. The Pales weevil killed young trees which were planted immediately after the stand had been cut, and necessitated delaying the planting one or more years, thereby further handicapping the young pines in their already unequal struggle with the competing vegetation. Another weevil killed the leaders of the most promising young pines, turning them into forked or crooked trees. Then the blister rust made its appearance and killed large numbers of white pines before it was brought under more or less control by eradicating the currant and gooseberry bushes growing near the trees.

The climatic climax consists primarily of hemlock (*Tsuga canadensis*), beech (*Fagus*

grandifolia), sugar maple (*Acer saccharum*), and black birch (*Betula lenta*). This is the first instance in which black birch has been found as a component of the climax forest, the more usual birch being the yellow birch (*B. lutea*). A physiographic climax is also recognized, growing on the ridge tops and also on the dry glacial outwash soils in the lowlands. This is a hemlock–white pine association, with beech, black birch, and red maple (*Acer rubrum*) as minor components. Complete destruction of the stand was followed by an even-aged stand of white pine, red oak (*Quercus borealis maxima*), and some hemlock. A disturbance before the climax had been reached did not always delay the attainment of the climax, but sometimes actually hastened it by destroying the pre-climax overstory and leaving the climax understory to form the new stand. In this particular area the climax stage was reached after about 400 years without disturbance.

The picture of the primeval forest which emerges from this study is quite different from the popular one of stagnant stands of immense trees stretching over vast areas with little change in composition. Instead, most of the stands were in a state of flux due to wind, fire, and other forces of nature.

The concluding paragraph is worth quoting in full as the key to successful silviculture: 'A forester who is capable of analyzing a given site in terms of the climax composition which will naturally develop there, and of determining the successional stage reached by the stand now on the ground has it in his power to practice silviculture in harmony with natural forces. In so doing, the authors believe, lies the greatest promise of minimizing the costs of crop production and maintenance, of affording the greatest security against destructive agencies and of building up a sound and enduring enterprise in forestry.'

Even in countries which have been inhabited for many centuries, as Britain has been, it is often possible for the keen observer to piece together bits here and there to form a reasonably accurate picture of the climax and of the stages leading to it. Even though, as often happens, economic considerations may call for a stand different from the climax or any of the stages leading to it, much wasted effort can often be saved by a knowledge of the natural forces at work, because, in the last analysis, these forces determine which measures are certain to fail and which are reasonably sure of success.

Forestry Terminology, a Glossary of Technical Terms Used in Forestry. Compiled and edited by the Committee on Forestry Terminology, Ralph C. Hawley, Chairman. Published by the Society of American Foresters, 1944.

THIS is an excellent Glossary. The development of forestry has led to its increasing subdivision into specialized branches, each with its own nomenclature. The practising forester, and indeed even the academic forester, often comes across terms when reading technical journals which convey nothing to him. We do not say that he will find all such in this glossary, but it will go a long way to help him. A selection at random is Lapachol, Chi/square, tylosoid, and the Spaulding rule. The definitions are on the whole simple and lucid, although in some instances specialists may not be quite satisfied.

The Society of American Foresters have used part of the Schlich Memorial Award to enable it to present copies of this publication to forestry societies, University forestry departments, &c. The thanks of this society have been sent to its sister society in America for such a gift.

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